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Supply Chain Planning: Inventory Optimization through the Demand Forecasting Tools and Algorithm

TESI DI LAUREA MAGISTRALE IN
MANAGEMENT ENGINEERING
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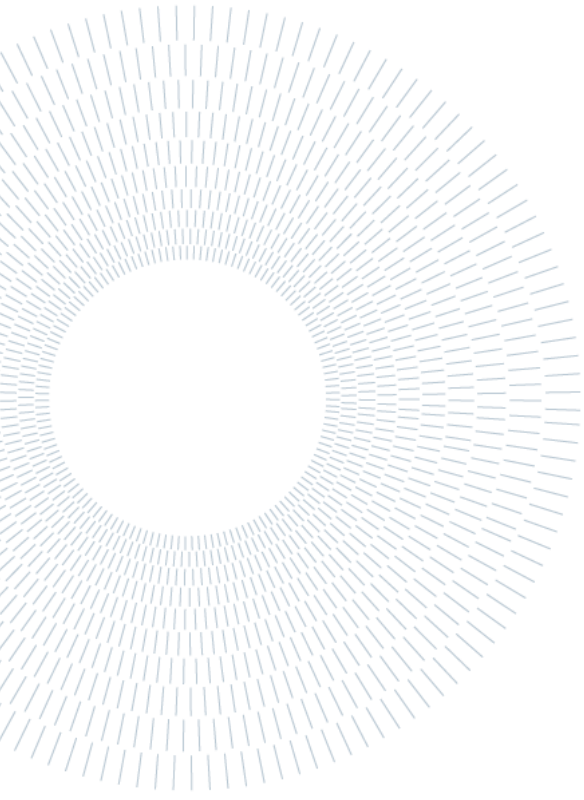

Abstract

Planning sales and their related inventories along the different steps of the supply chain is becoming increasingly crucial for companies in the goal of reducing costs while maximizing efficiency. Due to this fact, the planners are increasingly being supported by demand forecasting tools. According to software companies and their various implementers, enhancing demand forecasting automatically leads to leaner inventory management. In this thesis, we will seek to comprehend the current state of the supply chain planning procedure by utilizing not only academic articles but also real-world solutions and practical examples. In addition, quantitative-mathematical and qualitative aspects of the relationship between Demand and Inventory planning will be investigated in order to comprehend their mutual benefits. The results of the reported practical case will be helpful for understanding the rationale behind why improving forecasting capabilities with the aid of a tool also improves stock management from both a performance and a process perspective. Lastly, these provide a foundation for deeper and more extensive verification over time so that the inherent relationships between demand and inventory planning and the impact of forecasting tools are clarified even further.

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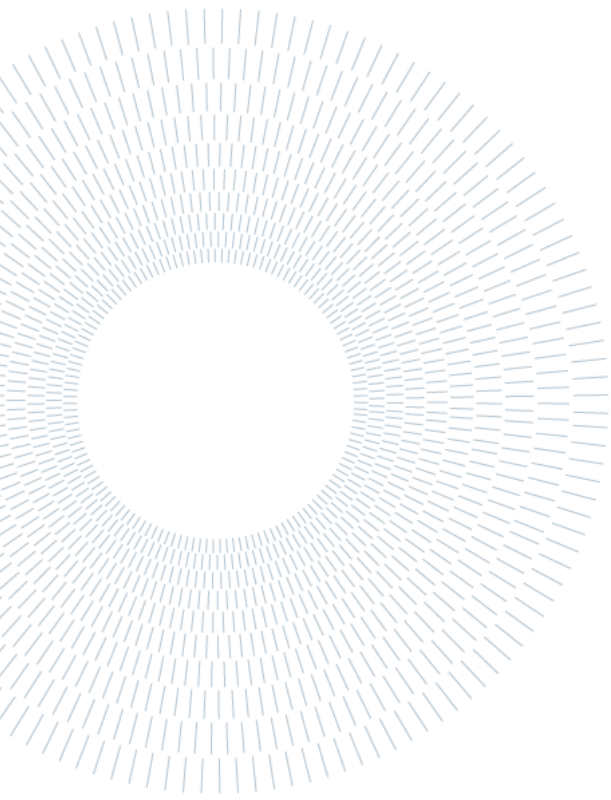
Abstract in italiano

La pianificazione delle vendite e delle relative scorte lungo le diverse fasi della catena di fornitura sta diventando sempre più cruciale per le aziende, con l'obiettivo di ridurre i costi e massimizzare l'efficienza. Per questo motivo, i pianificatori sono sempre più supportati da strumenti di previsione della domanda. Secondo le aziende produttrici di software e i loro vari implementatori, il miglioramento della previsione della domanda porta automaticamente a una gestione più snella delle scorte. In questa tesi, cercheremo di comprendere lo stato attuale della procedura di pianificazione della supply chain utilizzando non solo articoli accademici, ma anche esempi pratici e reali. Inoltre, verranno analizzati gli aspetti quantitativi-matematici e qualitativi della relazione tra la pianificazione della domanda e dell'inventario, al fine di comprenderne i vantaggi reciproci. I risultati del caso pratico riportato saranno utili per comprendere le ragioni per cui il miglioramento delle capacità di previsione con l'aiuto di uno strumento migliora anche la gestione delle scorte, sia dal punto di vista delle prestazioni che dei processi. Infine, questi forniscono una base per una verifica più approfondita ed estesa nel tempo, in modo da chiarire ulteriormente le relazioni intrinseche tra la pianificazione della domanda e delle scorte e l'impatto degli strumenti di previsione.



Contents

Introduction

1 SUPPLY CHAIN AND SUPPLY CHAIN MANAGEMENT

In this paragraph we will give a definition of what supply chain is (1.1) and how it could be managed (1.2) and designed (1.3) based on the external context

1.1. SUPPLY CHAIN

1.1.1. SUPPLY CHAIN DEFINITIONS

The supply chain is a concept that, over the past 50 years long time, picked up incredible consideration in scholarly writing. It has been defined in numerous ways, usually in association with the definition of Supply Chain Administration. Among the foremost utilized definition of Supply Chain, Mentzer et al. [2001] characterize it as:

A set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flow of products, services, finance, and/or information from a source to a customer.

Lambert et al. [1998] define it as:

The alignment of firms that brings products or services to markets.

And La Londe and Masters [1994] define it as:

The integrated movement of materials throughout the firms in a organic and systemic way.

These definitions incorporate as it were a particular section of the goods stream that goes from the initial source of materials to the ultimate consumption. On the other end, Stevens [1989] defines it as:

The interconnected series of activities concerned with the planning and controlling of raw materials, components and finished products from suppliers to the final consumer

This author is including therefore all the players (directly) involved in a production process, included the final customer. A third alternative is the definition provided by Van Drunen (KPMG [1]):

A supply chain is a framework of organizations, individuals, activities, information and resources involved in moving a product or service from provider to client. Supply chain activities involve the transformation of normal assets, raw materials, and components into a finished goods that is distributed to the final client.

[1] KPMG was founded in 1987 after merging Peat Marwick International and Klynveld Main Goerdeler. It is a global network of professional firms providing Audit, Tax and Advisory services. They operate in 155 countries and have more than 162,000 people working in member firms around the world. Its global headquarter is located in Amsterdam, Netherlands.

It focuses on a specific firm, and than define the SC from it selecting the segment of the product flow that goes from its supplier's supplier to its customers' customer.

All these definitions can be analyzed regard to the two dimensions that define the scope of a supply chain (Cooper et al. [1997]):

a) **Length**: it represents number of tiers across the supply chain. First of all the focal company (tier 0) must be defined as: the firm that is governing over the supply chains, providing direct contact to end customers, and having bargain power over other actors in the supply chain the most influential company in the chain. Then, the tiers 1 consists in the focal's company direct suppliers and customers . Finally the tiers 2 consists in its suppliers' suppliers and customer's customers (tier 2), and so on up or down the chain to the first sources or to the points of consumption (n-th tiers)

b) **Width:** it represents the number of suppliers/customers represented within each tier instead the activity, and therefore the typology of firms involved: from the only commercial or industrial firms to companies not directly involved in this type of activities (a,b in focal's company tier): Logistic Service Provides (LSP), financial institution and all the enterprise that have a relationship with the focal company.

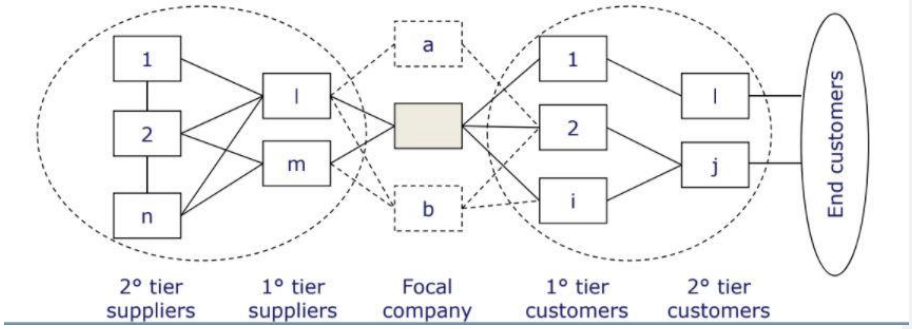


Figure 1.1: The supply chain, "Introduction to SCM", slide 3, 2019-2020 Supply chain management course

Mentzer et al. [2001] state that, regarding these two dimensions, three supply chains can be defined: the "direct" (fig. 1.2(a)), the "extended" (fig. 1.2(b)), and the **"ultimate" (fig. 1.2(c)) supply chain**.

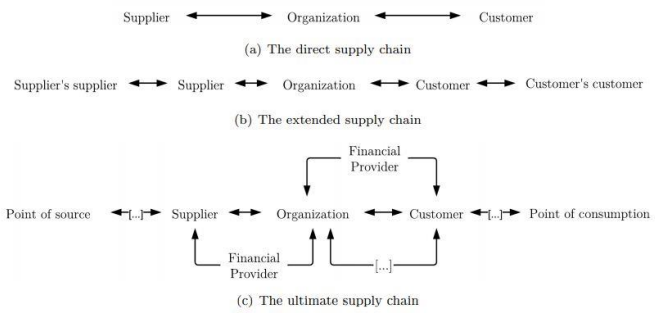


Figure 1.2:The three supply chains defined by Mentzer et al. [2001].

1.1.2. SUPPLY CHAIN EVOLUTIONS

The Supply Chain is not something static but it is something always in evolution by its definition, so in order to have a clearer idea of this transformation process, it is interesting to quote the 5 step supply chain maturity model offered by Poirier and Quinn (2004) in their article "How are we doing? A Study of Supply Chain Progress" (see Figure 1.2).

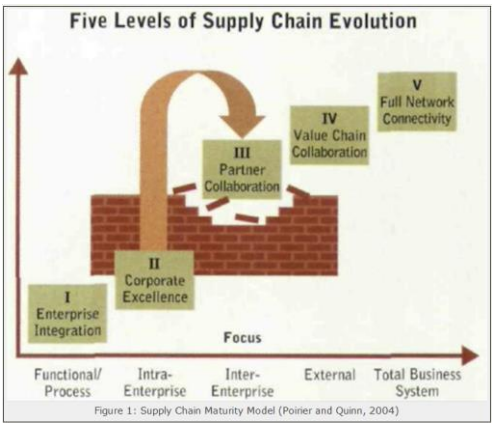


Figure 1.2 : Supply chain maturity Model (Poirer and Quinn, 2004

The primary stage of the Poirier and Quinn model includes undertaking integration that endeavors for corporate alignment (vertical integration), the second one attains

corporate excellence (efficiency and effectiveness). The focus of the first 2 stages is internal (intra-enterprise).

In the third phase, organizations look externally to develop partner collaboration. In phase four, supply chain partners work to form esteem chain collaboration (improved supply chain transparency and visibility).

The aim of these final two stages was to decrease costs while improving delivery quality since each stakeholder is presently centered on fair one portion of the process. Within the fifth and last stage, when business is getting to be as well complex for fair a single company, supply chain partners accomplish full organize network in arrange to better respond to more dynamic requests and to quicken the globalization pace. Thus, enterprises begun started to forge closer partnership with their stakeholder, attempting to retain customers and keep up the leading edge in an progressively competitive environment.

Just to end this paragraph and have a clue on what has been presented: during the supply chain evolution the companies, belonging to the same chain, must become more integrated by increasing the collaboration between upstream and downstream partners (Done, 2011). This would allow them to achieve better results and benefits.

Nowadays, in order to achieve the 5th step of the model and having an optimal integration and collaboration it is clearly required the exchange of more complex elements at the expertise and knowledge levels then physical resources and information flow. In achieving this stage, the new trend of technology like cloud computing (Software as a service deployment) and the IoT for sure will help .

1.2. SUPPLY CHAIN MANAGEMENT

After having understood what supply chain is, now it is the turn to its managerial part. In this segment, even with the goal to create a background knowledge of the thesis, we start with the definitions (1.2.1), then the reader will understand which are the main problem that a supply chain manager will face in the integrations of the different blocks (1.2.2) and how to overcome them (1.2.3). In the end there is an understanding of which are the benefits generated (1.2.4).

1.2.1. SUPPLY CHAIN MANAGEMENT DEFINTION

In the literature there are several definitions of Supply Chain Management (SCM) that could be little different depending to the author. Due to the simplicity it has been decided to go straight to the most complete one, given by the Council of Supply Chain Management Professionals (CSCMP):

"Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance and information technology".

1.2.2. SUPPLY CHAIN MANAGEMENT BARRIER

Even though the manage a group of companies as a "unique body" will bring a lot of benefits, that will be listed in the next paragraph, its implementation is not easy. Considering supply chain coordination and integrations, the main barriers to an effective SCM implementation are grouped by Dianty et al. (2001) as follows:

- **Problems related with attitude (mentality)**: Parochial 'win-lose' attitude, short-term focus, subcontractors and suppliers not being allowed to participate in the early stages of the production process, lack of; praise for good performance and understanding of sub-contractors‟ and suppliers‟ problems. To this one we can also put: lack of senior management and partners commitment, lack of understanding the concept of supply chain management (Akintoye et al. (2000)).

- **Problems related with the quality of information**: Low information quality, insufficient information exchange and, less transparency along with limited

communication. In addition to this group we can quote: failure to develop measures for monitoring the alliance and failure to expand the vision of the supply chain that comprises the major business processes in addition to purchasing or distributing products (Vrijhoef et al. (2001))

- **Financial/cost related problems:** Competitive tendering procedures which are based on the price but not on lifecycle costs, serious problems with payments between customers, main contractors, sub-contractors and suppliers due to hostile relationships. This point is very fundamental for this thesis

- **Programming/timing related problems:** Unrealistic and uncertain supply time of materials and equipments.

1.2.3. SUPPLY CHAIN MANAGEMENT TECHINQUES

Commentato [GM3]: Techniques?

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As it has been seen in the previous paragraph, it could be very tough to go ahead of the initial inertia. In this segment we want to provide some general technique used to overcome the problem since the beginning. The solution proposed are grouped in 2 part: the first one comes from the academy and it is related to the article "Supply Chain Management Techniques in Medium-to-Small Manufacturing Firms", written by Higginson and Alam (1997). The second consists in a report published by McKinsey. The academic one explains in a very complete way the most common techniques of supply chain management. These are the followings:

• Creating solid and long-term relationship with supply chain member to increase the quality of the product and services, decrease costs and create more efficient and effective process;

• Managing with less providers and carriers to energize closer working connections and permit more prominent utilize of provider and carrier expetise;

• Working with SC individuals to decrease channel-wide stock levels and cycle times, in this way making strides the customer service whereas decreasing costs;

• Routinely sharing data with other supply chain members permitting speedier reactions to changes;

• Working with SC individuals to preserve high quality products and services

The second one summarized the method made by 7 points through which the McKnsey's consultants are trying to overcome the barriers:

1) Organization structure: Entrepreneurs should be able to give some authority to employee leaders because most entrepreneurs manage their organization themselves, as the owners; they do not delegate authority to others, and sometimes this is the pitfall of this management style.

2) Management strategy: Entrepreneurs should develop their organization by using software to help management areas such as stock and inventory, accounting, orders, and purchases. This type of software can help them manage their materials precisely. In addition, in order to increase the bargaining power, they can collaborate to order goods from suppliers, which would give them the power to negotiate to reduce costs.

3) Systems: This issue is very important and can help an organization's work efficiency; for example, we found many construction shops use radio commander to help to communication between managers and employees, or between employees.

4) Styles: Entrepreneurs should embrace modern styles and technologies. For example, using GPS in trucks for delivering goods to customers can reduce the cost of transportation by saving time because of no lost drivers. In addition, the management styles of owners are very important because they have to perform many rule of the organization and how they handle various situations depends on their style of management.

5) Skill: Companies often do not send employees to training, most of them train by doing, so sending employees to train at outside organizations can help them gain more knowledge and can refresh their work attitudes. In addition, owners should also go to outside training in areas such as modern management or marketing strategy. This will help them be receptive to new ideas to develop their business and transfer knowledge to their employees.

6) Staff: Job development is important, and is completed by creating employee motivation using various tools. These tools include raises in income, greater benefits, and year-end bonuses. These could motivate the employees to work more efficiently and feel more responsibility to their organization.

7) Shared values: Creating a strong organizational culture and letting employees help set up the culture is important because it can help people work well and can make a business survive; however, a good organizational culture needs serious support from the owner and manager.

In addition, in order to use supply chain management for business success, SME construction shops should create production lines to produce material that is not difficult, for example, concrete blocks, and should provide free delivery if the customer orders a high volume. The material should be sent on time and the organization should guarantee that they will take back the product if it is substandard and the customer is unsatisfied. In addition, stock and inventory affects the material's quality; however, from the study we found that many shops do not maintain a good inventory, so they should design the store to have modern systems in order to promote easily accessed materials.

1.2.4. SUPPLY CHAIN MANAGEMENT BENEFITS

Coming to the end of this paragraph, it is the time to explicit which are the main benefit of managing the supply chain as a "concert" of companies rather than a silos. Researches as Mainardi et al. [1999], Gryna [2001], Jacobs [2004], Mentzer et al. [2001] have provided some examples in their papers that cope with effectiveness, efficiency, supply chain visibility and uncertainty:

a) Increased company productivity and profitability (les the transactional costs, integrated NPD) included employees productivity;

b) Reduced risks (procurement shortage);

c) Improved cash flow cycle time

d) Reduce purchasing price (scale economy)

e) Savings on inventories carrying and other logistics costs

f) Improved quality of the services provided, such as the ability to meet customer requests

g) Integration of Processes (reduce the lead time and the time to market)

h) Build and Maintain Long-Term Relationships

i) Mutually Sharing Information (supply chain visibility)

1.3. SUPPLY CHAIN DESIGN

In order to reach the supply chain management Benefits, previously listed, it is really important to take wright and consistent decisions a long of each step of the chain. The next paragraph will take into consideration the Strategical (1.3.2), Planning/Tactical (1.3.3), Operational Decisions (1.3.4) that a Supply Chain Manager has to take in order to build a resilient Supply chain

1.3.1. The different type of Decisions

The scheme provided by Rohde, Meyr and Wagner (Structure of Advanced Planning Systems) helps the reader to understand their scope.

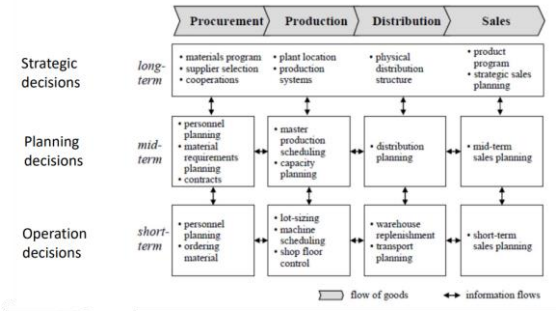

Figure 1.3 Supply chain Scheme, Structure of Advanced Planning Systems (Rohde, Meyr and Wagner 2005)

In the following paragraphs, the reader will go through to the analysis of all the decision levels.

1.3.1.1. Strategic Supply Chain Decision

In this paragraph we could take into consideration:

The scope of the supply chain's strategical part contains the structure of the supply chain and what processes each stage will perform as the following ones:

- Locations and capacities of facilities
- Products to be made or stored at various locations
- Modes of transportation
- Information systems

It is important to state that the Supply chain design must support strategic objectives and they are long-term and expensive to reverse, so they must take into account market uncertainty.

1.3.1.2. Planning/Tactical Decision

a) The definition

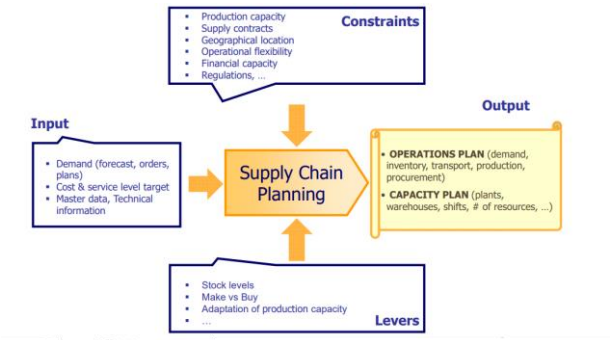

Figure 1.4 Supply chain decision

The supply chain planning decisions start with a forecast of demand in the coming year, the definition of Cost and Service level target (input) and consists in the definition of a set of policies (Output as Operation and Capacity Plan) that govern medium-short term operations, fixed by the supply configuration (Constraints) from previous phase (Strategic one). The decision (levers) that could be taken are for example:

- Which markets will be supplied from which locations
- Planned build-up of inventories

- Subcontracting, backup locations
- Inventory policies
- Timing and size of market promotions

It is important to consider in planning decisions demand uncertainty, exchange rates, competition over the time horizon.

Lastly, A picture provided by the APICS
(American Production and Inventory Control Society), will help the reader in understanding the complex scope of Supply chain Planning composed by the following parts

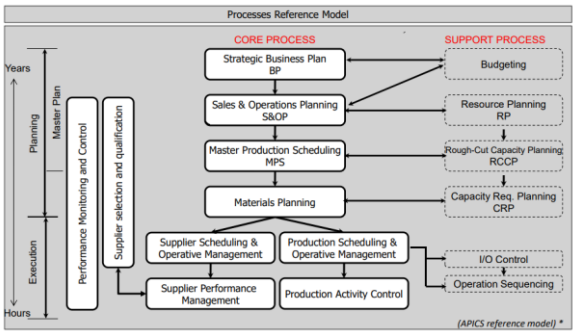

Figure 1.5, Supply Chain Planning Scheme (Apics)

- Business Planning: It consists in a process made by different steps as follows:
  - Identification of the reference performance measures
  - target values setting
  - Break-down of performance targets (according to a top-down approach), definition of plan(s) and corresponding resources
  - Consolidation of budgets, consistency check, calculation of the value of performance indicators and comparison with target performances
- Sales and Operations Planning: S&OP is a process that directs operations strategically to continuously gain a competitive advantage through integration of customer-oriented marketing plans, both for new and existing products and supply chain management. This process gathers all the business plans (sales, marketing, new product development, manufacturing, purchasing, and finance) into a single planning cluster. (APICS)

- Master Production Schedule: It consists in a process of allocating the quantities to be produced to the different time periods. Two different approaches could be performed:
    I. Level: It aims to contain the costs of production (set-up, labor, overtime, etc.). All differences between the production rate and demand are absorbed with inventories. It is used when the focal company needs to exploit scale economy's benefit
    II. Chase: It aims to contain the amount of stock and corresponding maintenance costs. The following are generally incurred higher costs of production (set-up, labour, overtime, etc.). It is used when the focal company is required to be flexible due to the uncertain environment
- Materials Planning: Starting from Final Assembly line schedule, Bill of Material, and on-hand inventory, MRP performs the calculation of requirements of parts and components are computed by time and it plans their fulfillment (plan timed orders). More in depth, the requirements are lot-processed to take into account technical or economical constraints. The lots are "time-phased", depending on specific production or purchasing Lead Times. Lastly, the information is transmitted upstream, to the first actor in the production chain, and it then "pushes" the flow of materials

1.3.1.3. Operational Decision

The decisions regard the individual customer order and take place into a fixed Supply chain configuration and determined operating policies. The main goal is to implement the operating policies as effectively as possible in:

- allocating orders to inventory or production
- setting order due dates
- generating pick lists at a warehouse
- allocating an order to a particular shipment
- setting delivery schedules
- placing replenishment orders.

Now the reader has a complete overview of the supply chain and the rules it follows so we could deep dive into the Demand Management process.

1.4. Demand Management

In today's dynamic and competitive business environment, effective demand management has become a cornerstone of successful supply chain operations and business planning. Demand management involves a systematic approach to understanding, forecasting, and managing customer demand to ensure that organizations can efficiently meet market requirements while optimizing resources. This section delves into the objective, tasks, and outputs of the demand management process, with a particular focus on the integral components of demand forecasting and planning. In this paragraph we will deeply develop what demand management is: starting from its objective (2.1), then taking into consideration its relationship with the Supply chain Decoupling point (2.2) and the main task of which it is composed by (2.3)

1.4.1. Demand Management Objective

The primary objective of demand management is to align an organization's supply capabilities with customer demand to achieve operational efficiency, cost-effectiveness, and customer satisfaction. This entails avoiding stockouts and overstock situations, optimizing inventory levels, and enhancing overall responsiveness to market changes. In essence, demand management aims to strike a balance between customer expectations and available resources.

1.4.2. Demand management and The Decoupling Point.

The decoupling point in supply chain management refers to the stage in the production and distribution process where inventory is separated into different streams, allowing the supply chain to be divided into two distinct segments: the make-to-stock (MTS) and the make-to-order (MTO) segments. The decoupling point marks the boundary between the stages where products are produced based on forecasts (MTS) and where they are produced based on actual customer orders (MTO)

Demand management plays a pivotal role in determining the optimal location of the decoupling point within the supply chain. The decoupling point is influenced by factors such as demand predictability, product customization, lead times, and inventory costs. Effective demand management strategies can help organizations determine the appropriate level of customization, the extent of inventory to be held, and the positioning of the decoupling point to strike a balance between responsiveness and efficiency. For products with high demand predictability and relatively stable demand patterns, the decoupling point can be positioned further

upstream, allowing for economies of scale and efficient production processes. On the other hand, products with volatile and uncertain demand patterns may necessitate a decoupling point closer to the customer, enabling more responsive production based on actual orders.

1.4.3. Demand Management Practices

Strategic demand management practices enable organizations to enhance demand visibility, accurately predict customer requirements, and align the decoupling point with demand characteristics. This synchronization between demand management efforts and the positioning of the decoupling point contributes to improved supply chain flexibility, reduced lead times, minimized excess inventory, and optimized customer service levels.

These practices consists in a series of interconnected tasks that can be categorized as follows:

- Demand Forecasting and Shaping
- Demand Planning
- Inventory management and Planning
- Collaborative Forecasting

These four tasks will be deeply analized in the following paragraphs highling the main goal, the related activities and the output

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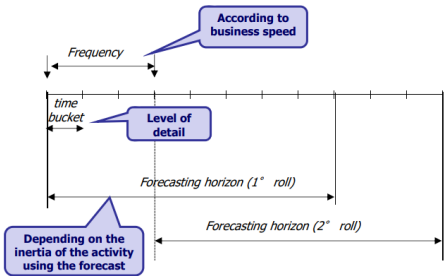
1.4.3.1. Demand Forecasting

Accurate demand forecasting forms the bedrock of effective demand management. It considers the demand as an exogenous variable and the idea behind this group of activities is that by analyzing historical data, market trends, economic indicators, and other relevant factors, organizations can estimate future demand patterns. This information serves as the basis for making informed decisions about production, inventory, and distribution.

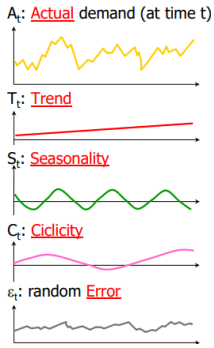
The main activities consists in:

- Objective Definition: in this first phase, it is decided the main goal of the forecast that for example could be giving an Input to the planning activities (capacity, operations) or supporting the Sales force
- Define What to Forecast: in this second phase the forecasting scope is decided as the units (Boxes, Kg, €), the aggregation level (Pieces, order, orders rows), the geography (Store, ZIP, region, country)
- Define the time bucket, horizon and frequency



Objective	Forecast
Define the storage capacity at the main Distribution Center	• Aggregation = logistics family • Bucket = month • Horizon = 1-3 years
Plan production and supply	• Aggregation = commercial / production family • Bucket = Week • Horizon = 3-6 months
Distribution planning	• Aggregation = SKU, per each logistic target • Bucket = week / day • Horizon = 1-2 weeks

Figure 1.6 and 1.7 Demand Forecasting Variables (advance Planning 2019-2020 Course)



- Data collection and cleaning: the input data are mapped, collected, cleaned and elaborated. For example the historical sales is separated among its component as Trend, seasonality and Ciclicity

- Exploratory Analysis: this step consists in exploring Exploring the relationship among data through statistical tools and algorithm

- Forecasting techniques and algorithms selection: The experienced analyst knows that "one size does not fit all". In other words, a well performing forecasting algorithm is not said to keep on forecasting well If the circumstances and input data changes. The literature is plenty of forecasting techniques and algorithms that could fit different situation, and part of them will be analized in the dedicated paragraph. Lastly, it is important to say that the exploratory part executed in the previous step comes for useful in selecting the algorithm.

- Define the target accuracy in terms of forecast error. The target accuracy is the result of a cost optimization equation that takes into consideration the forecasting error cost as overstock and Stock out with related consequencies as higher space rent, late deliveries, production stoppages and the forecasting process cost needed to increase accuracy as tool, human resources.

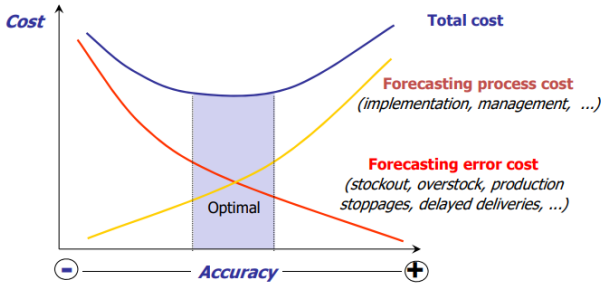


Figure 1.8 Demand Forecasting Optimization (advance Planning 2019-2020 Course)

Lastly the output consists in Accurate demand forecasts providing the foundation for all subsequent activities within the supply chain. They guide production schedules, inventory levels, and procurement decisions.

1.4.3.2. Demand Planning:

Once the demand forecasts are generated, the next step is demand planning. Demand planning involves translating the forecasts into actionable plans that guide production schedules, inventory replenishment, and resource allocation. It encompasses determining how much to produce, when to produce, and what inventory levels to maintain.

1.4.3.3. Inventory Management:

Efficient inventory management is crucial to demand management. Organizations need to strike a balance between carrying enough inventory to meet demand without incurring excessive holding costs.

This part of demand management process consists in the following activities:

- Definition of an Objective: it is the reason behind I need the stock
    - To offer great service ("I want it and I want it now"
    - To save money (quantity discount, speculative stocks)
    - To optimize (production and logistics) costs
    - To dampen uncertainty (demand, production, transportation)

- To buffer / decouple operations phases
- To accomplish process transformation (e.g. wine, rubber)
- To show off
- To transfer information

- Product Categorization: The inventory management policy could be different and based on product characteristics, that's why we need to create product categories. A product could be categorized for the following features:
  - Demand
    - Demand volume
    - Demand stability:
      - Continuous demand:
      - Intermittent demand / slow movers:
      - Lumpy
    - Demand commonality:
      - Few customers
      - Multiple customers
  - ◎ Product features:
    - Physical / Logistics requirements
    - Economic features
  - Market:
    - Product positioning
      - Flagship
      - Standard
    - Lifecycle positioning
      - Newly introduced
      - Mature
      - Decline
  - Supply
    - Supply Lead time

- Scarcity / supply reliability
- Quality of supply

1.4.3.4. Inventory Positioning Definition :

Inventory positioning refers to the strategic placement of inventory within the supply chain to optimize its availability and distribution. It involves determining where to store inventory at different stages of the supply chain, such as warehouses, distribution centers, retail stores, or even directly with suppliers. The goal of inventory positioning is to achieve a balance between minimizing costs and meeting customer demand effectively. By strategically positioning inventory, organizations can reduce transportation costs, lead times, and stockouts, while also improving overall supply chain efficiency.

The choice of inventory positioning depends on factors such as demand patterns, lead times, transportation costs, and the desired level of customer service. Items with high demand variability or longer lead times might be positioned closer to the end customer to ensure quick response to fluctuations in demand. Conversely, items with stable demand and shorter lead times could be positioned further upstream in the supply chain.

1.4.3.5. Inventory Approach and Model Definition:

The approach in the inventory planning process refers to the methodology or strategy that an organization employs to manage its inventory effectively. There are several approaches that organizations can adopt, each tailored to their specific needs, industry, and supply chain characteristics. Some common approaches include:

- Just-In-Time (JIT) Approach: The JIT approach aims to minimize inventory levels by receiving materials and producing goods only when needed. It relies on close coordination with suppliers and emphasizes reducing waste, lead times, and excess inventory.
- ABC Analysis: This approach categorizes inventory items into groups based on their value or importance. The "A" items represent high-value, critical items that require close monitoring, while the "C" items are lower-value items that are managed with less scrutiny.
- Economic Order Quantity (EOQ) Approach: EOQ focuses on finding the optimal order quantity that minimizes the total cost of inventory, considering both ordering costs and holding costs. Its formula is:

$$EOQ = \sqrt{\frac{2 * Emission\ order\ Cost * Number\ of\ Orders}{Holding\ Cost * Cost\ of\ Product\ (producion\ or\ Procurement)}}$$

- Safety Stock Approach: Safety stock is a buffer inventory held to mitigate uncertainties in demand and lead times. This approach involves calculating and maintaining an appropriate safety stock level to prevent stockouts.

Considering the situation in the picture:

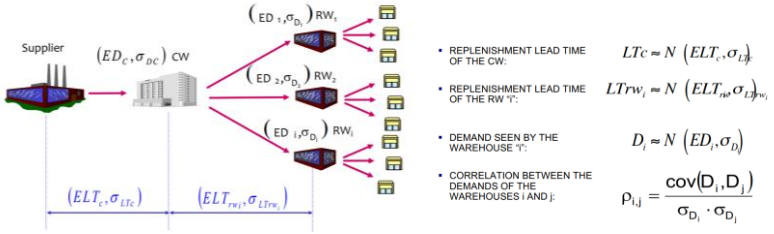


Figure 1.9 Demand Variation (Supply Chain Planning Course, 2019-2020)

Where:

- CW= Central wharehouse
- RW= Regional Wharehouse
- ELT= Expected Lead Time
- ED= Expected Demand
- I= ithRegional Wharehouse

The Safety Stock Formula for the ith regional Wharehouse will be:

$$SS_{RW_i} = k \cdot \sqrt{(ELTc + ELTrw_i) \cdot \sigma_{D_i}^2 + ED_i^{\,2} \cdot \sigma_{LTc+LTrw_i}^2}$$

- Vendor Managed Inventory (VMI): In VMI, suppliers take responsibility for managing inventory levels at the customer's location. This approach requires close collaboration and sharing of data between the supplier and the customer.
- Cross-Docking: Cross-docking involves receiving goods from suppliers and immediately transferring them to outbound trucks without storing them. This approach reduces storage costs and minimizes inventory holding time.
- Multi-Echelon Inventory Optimization: This advanced approach optimizes inventory levels across multiple tiers of the supply chain, considering demand variability, lead times, and cost structures.

The choice of approach depends on factors such as the nature of the products, supply chain complexity, demand patterns, and the organization's overall strategic goals. An effective inventory planning approach ensures that inventory is managed efficiently, enabling organizations to meet customer demands while minimizing costs and maximizing operational performance

1.4.3.6. Parameters Definition:

In the case they are not previously defined, we need to size the following parameters:

- Ordering frequency for cycle stock
- Replenishment Policy for Safety stock:
- Percentage of Free Stock (advanced)

1.4.3.7. Collaborative Forecasting:

Collaborative forecasting involves engaging key stakeholders across the supply chain, including suppliers, distributors, and retailers, to share insights and data related to demand. This collaboration improves accuracy in demand forecasts and helps in aligning the entire supply chain with market dynamics.
Lastly, The collaborative forecasting process yields several outputs that contribute to more accurate and responsive demand forecasts:

- Improved Forecast Accuracy: Incorporating insights from stakeholders leads to more accurate forecasts that reflect real-world market conditions.
- Reduced Bullwhip Effect: Collaborative forecasting reduces the amplification of demand fluctuations as information is shared across the supply chain.
- Enhanced Supply Chain Visibility: Stakeholder collaboration improves visibility into demand changes, enabling proactive adjustments to production and distribution.
- Optimized Inventory Management: Accurate forecasts allow organizations to maintain optimal inventory levels, minimizing excess stock and stockouts.
- Higher Customer Satisfaction: Meeting customer demands more reliably enhances customer satisfaction and loyalty.

1.4.3.8. Demand Sensing and Shaping:

As markets become increasingly volatile and unpredictable, demand sensing and shaping have gained prominence.

- Demand sensing involves real-time monitoring of market signals and adjusting plans accordingly.
- Demand shaping involves using marketing and promotional strategies to influence consumer behaviour and steer demand in desired directions.

1.4.4. The supporting Models

Having clear how the demand and inventory management works from the process point of view, It is preparatory to the continuation of this thesis to go into more detail and understand what are the main qualitative and quantitative models that support the process.

1.4.4.1. Demand Forecasting Models

A forecasting model consists of a systematic and structured approach to predict future values, trends, or outcomes based on historical data, patterns, and qualitative relevant information. Its purpose is to provide valuable insights that help individuals and organizations make informed decisions, allocate resources, plan strategies, and adapt to changing circumstances. Then, we could identify 2 different types of forecasting methods:

- Qualitative: A qualitative forecast model involves making predictions about future events, trends, or outcomes based on subjective judgment, opinions, insights, and expert knowledge.
- Numerical: It involves mathematical, statistical, or computational techniques to analyze past observations and generate forecasts for future periods. This type could be differentiated among two main groups:
    - Time series: It considers just the past demand
    - Correlational: They consider the correlation between past demand and one or more external factors

Lastly, an analyst must respect some important rules in approaching to a forecasting model

- It must adapt the model to the nature of the forecasting problem and not vice versa
- He must use a mix of forecasting techniques, quantitative and qualitative, not just one technique
- The Model must be used as a vehicle for communication between those who generate and those who use the forecast plans
- He must communicate to users not only the forecasts, but also the estimated value of the error
- The model must include management mechanisms by exception(e.g., promos, ...)

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In the next paragraphs we will enter in detail of the 2 different types, higjliting their pros and cons

1.4.4.2. Qualitative Model

Qualitative forecasting relies on the expertise of individuals who possess relevant domain knowledge and insights to provide valuable input into the forecasting process. These models are used when historical data might be limited, unreliable, or not applicable due to unique or unprecedented circumstances. It follows a series of the selected 3 examples with a brief description:

- Expert Judgment: Experienced professionals provide their subjective opinions and insights based on their expertise and knowledge.
- Delphi Method: A panel of experts iteratively provides forecasts, and their individual opinions are refined through consensus discussions.
- Market Research: Gathering insights from surveys, focus groups, and market studies to gauge customer preferences and expectations.

Pros of Using Qualitative Forecasting Methods:

1. **Expert Insight:** Incorporates specialized knowledge and insights not captured by quantitative models.
2. **Adaptability and Flexibility :** It can be used when historical data is unavailable or unreliable, or we have to address unique situations/emerging trends that traditional models can't handle.
3. **Quick Response:** Suitable for making forecasts in rapidly changing environments.

Cons of Using Qualitative Forecasting Methods:

1. **Subjectivity:** Prone to individual bias, leading to potential inaccuracies.

2. **Lack of Precision:** Forecasts might lack the precision and reliability of quantitative models.
3. **Difficult to Replicate:** Hard to replicate or standardize the process due to its subjective nature.

For this first type of model we can conclude that it can provide valuable insights in situations where traditional quantitative models might fall short, but they also come with inherent challenges related to subjectivity and reliability.

1.4.4.3. Quantitative Model

A quantitative forecasting model is a mathematical or statistical approach used to predict future values, trends, or patterns based on historical data and numerical relationships. These models rely on quantitative data, such as numerical values and time series observations, to make predictions. Unlike qualitative methods that rely on expert opinions and subjective judgment, quantitative forecasting models aim to capture underlying patterns and relationships in the data to generate forecasts.

Usually it follows these steps:

1. **Problem Definition:** Clearly define the objectives, scope, and time horizon of the forecast. Determine the variables to be forecasted and their importance.
2. **Data Collection:** Gather historical data related to the variable of interest. Ensure data quality and completeness.
3. **Data Preprocessing:** Clean and preprocess the data to handle missing values, outliers, and inconsistencies.
4. **Exploratory Data Analysis (EDA):** Analyze the data to understand its patterns, trends, seasonality, and potential correlations with other variables.
5. **Model Selection:** Choose appropriate forecasting models based on the characteristics of the data and the desired outcomes.
6. **Model Training:** Use historical data to estimate the parameters of the chosen model. This involves selecting appropriate training periods and testing the model's accuracy.
7. **Model Validation:** Assess the model's accuracy and performance using validation techniques such as cross-validation or out-of-sample testing.
8. **Model Evaluation:** Evaluate the model's accuracy metrics (e.g., Mean Absolute Error, Root Mean Squared Error) to determine how well it performs on unseen data.
9. **Model Refinement:** Adjust model parameters, techniques, or algorithms based on the evaluation results to improve accuracy.

10. **Forecast Generation:** Use the refined model to generate forecasts for the desired time period.
11. **Scenario Analysis:** Perform sensitivity analysis to assess how changes in underlying assumptions or external factors affect the forecasts.
12. **Communication and Visualization:** Present the forecasts to stakeholders in a clear and understandable manner, often using visualizations.
13. **Monitoring and Feedback:** Continuously monitor actual outcomes against forecasted values. Update models and assumptions as new data becomes available.

Quantitative forecasting models can range from simple techniques like moving averages to more complex algorithms such as exponential smoothing, ARIMA, neural networks, and machine learning methods. These models are particularly effective when historical data is available and can be used to predict future outcomes based on observed patterns and trends in the data. An examples' list follows:

1. **Exponential Smoothing (ES):**
    - ES assigns different weights to past observations, with more weight on recent ones. It's useful for data with no trends or seasonality and is available in various forms like simple, double, and triple exponential smoothing.
2. **ARIMA (AutoRegressive Integrated Moving Average):**
    - ARIMA combines autoregressive (AR) and moving average (MA) components with differencing to handle non-stationary data. It's suitable for capturing trends, seasonality, and irregular fluctuations.
3. **Seasonal Decomposition of Time Series (STL):**
    - STL decomposes a time series into seasonal, trend, and remainder components. It's effective for handling complex time series with multiple patterns.
4. **Holt-Winters:**
    - Holt-Winters is a triple exponential smoothing model that accounts for level, trend, and seasonality. It's useful for data with both trend and seasonality.
5. **Prophet:**

- Developed by Facebook, Prophet is designed for forecasting time series with strong seasonal patterns and multiple seasonalities. It also handles missing data and outliers well.

The most important for that thesis are 3: Holt Winters, ARIMA and Prophet. We will deeply described in the following paragraphs, highlighting the calculation, Use case and Pros vs Cons

1.4.4.4. Holt Winters

The Holt-Winters forecasting model, also known as the triple exponential smoothing method, is used for time series forecasting, particularly when the data exhibits trends and seasonality. It extends the simple exponential smoothing method by introducing additional parameters to capture these components. The Holt-Winters model is especially useful when dealing with data that shows both trend and seasonality, as it accounts for these patterns in the forecast.

Formula for Forecast: The forecast $hFt+h$ for time $ht+h$ (h periods ahead) is given by: $Ft+h=Lt+h\cdot Tt+St+h-m(k+1)$

Where m is the seasonal period, and k is an integer such that $h-(+1)t+h-m(k+1)$ is nonnegative and as small as possible.

How Holt-Winters Forecasting Model Works:

1. **Initialization:**
    - The model requires initial values for three components: level (average), trend, and seasonal. These initial values are often estimated from historical data.
2. **Updating Equations:**
    - Level (Lt): The current estimate of the average value of the time series.
    - Trend (Tt): Represents the direction and slope of the data.
    - Seasonal (St): Captures periodic fluctuations in the data.
    - The updating equations are as follows:

Level Update: $Lt=\alpha\cdot Yt+(1-\alpha)\cdot(Lt-1+Tt-1)$

Trend Update: $Tt=\beta\cdot(Lt-Lt-1)+(1-\beta)\cdot Tt-1$

Seasonal Update: $St=\gamma\cdot(Yt-Lt)+(1-\gamma)\cdot St-m$

Where Yt is the observed value at time t, α, β, and γ are smoothing parameters, and m is the seasonal period.

3. **Forecasting:**

- The forecast for the next period (t+1) is given by the sum of the current level, the trend component, and the seasonal factor corresponding to the next period.

4. **Tuning Parameters:**

The smoothing parameters α, β, and γ control the influence of new observations and updates on the components. These parameters are tuned to optimize forecast accuracy.

- α (Alpha - Level Smoothing):
  - α controls the weight given to the most recent observation (actual value) when updating the level component (Lt) of the forecast.
  - The formula to update the level component is: $Lt=\alpha \cdot Yt+(1-\alpha)\cdot(Lt-1+Tt-1)$
  - Common values for α are between 0 and 1, representing the weight assigned to the current observation versus the past estimates. The closer α is to 1, the more weight the most recent observation holds.
- β (Beta - Trend Smoothing):
  - β controls the weight given to the difference between the current and previous level estimate when updating the trend component (Tt) of the forecast.
  - The formula to update the trend component is: $Tt=\beta\cdot(Lt-Lt-1)+(1-\beta)\cdot Tt-1$
  - Similar to α, common values for β are between 0 and 1. A higher β gives more weight to recent changes in the level, allowing the model to adapt to trends more quickly.
- γ (Gamma - Seasonal Smoothing):
  - γ controls the weight given to the difference between the current observation and the current level estimate when updating the seasonal component (St) of the forecast.
  - The formula to update the seasonal component is: $St=\gamma\cdot(Yt-Lt)+(1-\gamma)\cdot St-m$
  - Here, m represents the seasonality period. Similar to α and β, common values for γ are between 0 and 1. Higher values of γ allow the model to adapt more quickly to seasonal changes.

General Use Case: The Holt-Winters forecasting model is applicable when dealing with time series data that exhibits both trend and seasonality. It's commonly used in industries such as retail, manufacturing, and finance for demand forecasting, inventory management, and financial projections. For instance, retailers can use it to predict future sales and adjust inventory levels accordingly. Its ability to account for trends and seasonality makes it a powerful tool for capturing and forecasting complex data patterns.

Pros of Using Holt-Winters:

1. **Handles Seasonality:** Holt-Winters is effective at capturing both trend and seasonality patterns in time series data.
2. **Simple Implementation:** The model is relatively simple to understand and implement.
3. **Quick Adaptation:** Holt-Winters can adapt to changing patterns and trends in the data.
4. **Historical Performance:** Well-suited for data with a consistent historical pattern.
5. **Low Computational Demand:** The calculations involved are relatively simple, making it computationally efficient.

Cons of Using Holt-Winters:

1. **Sensitive to Parameter Selection and Noisy Data Handling::** Performance can be highly sensitive to the selection of smoothing parameters. In addition, Holt-Winters might struggle with data that has significant noise or irregular patterns.
2. **Limited Handling of Outliers:** Outliers can disproportionately affect the model and lead to suboptimal forecasts.
3. **Assumed Patterns:** Holt-Winters assumes patterns will continue into the future, which might not hold in all scenarios.
4. **Lack of External Factors:** It does not naturally incorporate exogenous variables that could impact the forecast.
5. **Limited Interpretability:** While components have interpretations, they might not provide as much insight as other models.

1.4.4.5. Arima

The ARIMA (AutoRegressive Integrated Moving Average) forecasting model is a powerful time series forecasting technique that combines autoregressive (AR) and moving average (MA) components with differencing to handle non-stationary data.

ARIMA is suitable for capturing trends, seasonality, and other complex patterns in time series data.

ARIMA Formula: The general formula for an ARIMA model is given as:

$Yt=c+\phi 1Yt-1+\phi 2Yt-2+\ldots+\phi pYt-p+\theta 1\varepsilon t-1+\theta 2\varepsilon t-2+\ldots+\theta q\varepsilon t-q+\varepsilon t$

Where:

- Yt is the observed value at time t.
- c is a constant term.
- $\phi 1,\phi 2,\ldots,\phi p$ are the AR coefficients.
- $\theta 1,\theta 2,\ldots,\theta q$ are the MA coefficients.
- εt is the white noise error term at time t.

Here's how the ARIMA model works:

1. Differencing: ARIMA starts by differencing the original time series data to achieve stationarity. Stationarity is crucial for time series analysis, as it ensures that the statistical properties of the data remain constant over time. Differencing helps remove trends and seasonality from the data.

2. Identifying Model Order (p, d, q):

- **p (AutoRegressive Order):**
    - The AR component represents the relationship between a current value and its past values (lagged values). The parameter p specifies the number of lagged terms to include in the model.
    - **AutoRegressive Order:** The autoregressive order p is determined by analyzing the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots of the differenced time series. These plots help identify the number of significant lags that should be included in the autoregressive component. Typically, you look for the point where the PACF plot cuts off significantly. This indicates the value of p
- **d (Differencing Order):**
    - The differencing order (d) indicates the number of times differencing is applied to make the data stationary.
    - **Differencing Order:** The differencing order d is determined by assessing the level of differencing required to make the time series stationary. You can use techniques like the Augmented Dickey-Fuller (ADF) test to check for stationarity. If the time series is not stationary

(has a trend or seasonality), you'll need to apply differencing until it becomes stationary. The d value is the minimum number of differencing steps required

- **q (Moving Average Order):**
    - The MA component represents the relationship between a current value and past forecast errors. The parameter q specifies the number of lagged forecast errors to include.
    - **Moving Average Order:** Similarly, the moving average order q is identified by analyzing the ACF and PACF plots of the differenced time series. You'll be looking for significant lags in the ACF plot that should be included in the moving average component. As with p, the value of q is determined by the point where the ACF plot cuts off significantly.
- **Parameter Tuning:** Iterate through different combinations of p, d, and q to find the model that minimizes the selected goodness-of-fit metric. This process may involve automated methods like grid search or more advanced optimization algorithms. Keep in mind that parameter selection and tuning can be an iterative process, and there's no one-size-fits-all approach. It requires a combination of domain knowledge, data exploration, and model evaluation to identify the most suitable values for p, d, and q. Additionally, tools like statistical software packages (e.g., Python's statsmodels library) often include functions to help automate parameter selection and model fitting.

3. Model Estimation: After differencing the data and determining the model order (p, d, q), ARIMA searches for the best combination of these parameters to model the data. This is often done using techniques like the Akaike Information Criterion (AIC) or Bayesian Information Criterion (BIC), which measure the goodness of fit and penalize complex models.

4. Model Fitting: The ARIMA model is fit to the differenced data using techniques like the Yule-Walker equations. This involves estimating the AR and MA coefficients that best capture the patterns in the data.

5. Forecasting: Using the fitted ARIMA model, forecasts for future values are generated by combining past observations, past forecast errors, and model parameters.

General Use Case: ARIMA is used in various fields such as finance, economics, and operations to forecast values like stock prices, sales, demand, and more. It's particularly useful when dealing with data that exhibits trends, seasonality, and

other time-dependent patterns. The model's ability to capture complex relationships in time series data makes it a valuable tool for forecasting future values based on historical observations.

Pros of Using ARIMA:

1. **Mathematically Rigorous:** ARIMA is based on well-established statistical principles, providing a solid foundation for forecasting.
2. **Handles Trends and Seasonality:** ARIMA can capture both trend and seasonality patterns in time series data.
3. **Interpretable Parameters:** The model's parameters (p, d, q) have intuitive interpretations, making it easier to understand the impact of each component.
4. **Flexibility:** ARIMA can handle univariate time series data with various patterns and complexities.
5. **Wide Applicability:** ARIMA is used in economics, finance, engineering, and various other fields for forecasting.

Cons of Using ARIMA:

1. **Data Stationarity Requirement:** ARIMA assumes that the data is stationary, which might require extensive differencing and transformation.
2. **Complex Parameter Selection:** Selecting p, d, and q requires trial and error, and the process can be time-consuming.
3. **Sensitive to Outliers:** Outliers can disproportionately affect the model and lead to suboptimal forecasts.
4. **Noisy Data Handling:** ARIMA might struggle with data that has significant noise or irregular patterns.
5. **Resource-Intensive for Long Series:** Computing ARIMA can be resource-intensive for long time series.

1.4.4.6. Prophet

Prophet is a forecasting model developed by Facebook that is designed to handle time series data with strong seasonal patterns, multiple seasonalities, and holidays. It's especially useful for data that includes missing values, outliers, and changing trends. Prophet aims to provide an easy-to-use and automated solution for time series forecasting.

Prophet Formula: The Prophet model does not rely on a single formula like traditional time series models. Instead, it combines the trend, seasonality, holiday effects, and possible regression effects to generate forecasts.

Here's how the Prophet forecasting model works:

1. Decomposition: Prophet decomposes the time series data into three main components: trend, seasonality, and holidays. The trend component captures the underlying growth or decline in the data over time. The seasonality component models recurring patterns within the data, often with multiple seasonalities (e.g., daily, weekly, yearly). The holiday component accounts for special events and holidays that can impact the time series.

2. Automatic Changepoints: Prophet automatically detects changepoints in the data where the trend shifts direction. These changepoints are points in time where the trend changes from increasing to decreasing or vice versa. Prophet identifies these changepoints by analyzing the rate of change in the data.

3. Handling Missing Data and Outliers: Prophet is designed to handle missing data and outliers gracefully. It can model missing data points by using a piecewise linear approximation of the trend. Outliers are treated by including them in the model but applying a dampening effect on their influence.

4. Holiday Effects: Prophet allows you to specify holidays and events that can impact the time series data. It includes the effects of holidays in the model, enabling the forecast to account for changes in behavior during holiday periods.

5. Regression Effects: Prophet allows you to include additional regressor variables that can influence the forecast. These variables can be external factors such as economic indicators or marketing campaigns.

General Use Case: Prophet is widely used for forecasting in various industries, including retail, e-commerce, finance, and supply chain. It's particularly beneficial for data with strong seasonal patterns, multiple seasonalities, and special events that can affect the time series. Here are a few common use cases for the Prophet forecasting model:

1. **Retail Sales Forecasting:** Predicting sales for retail products with daily, weekly, and yearly seasonality along with holiday effects.
2. **Demand Forecasting:** Forecasting demand for products or services that experience variations due to holidays, promotions, or events.
3. **Website Traffic Prediction:** Forecasting website traffic considering daily and weekly patterns as well as the impact of holidays and marketing campaigns.

4. **Supply Chain Planning:** Predicting inventory requirements and production needs considering multiple seasonalities and holidays.
5. **Financial Forecasting:** Forecasting stock prices, commodity prices, and financial indicators while accounting for trading days and holidays.

Prophet's ability to handle complex time series patterns and its user-friendly implementation make it a popular choice for forecasting when traditional time series models might not provide satisfactory results.

Pros of Using Prophet:

1. **User-Friendly:** Prophet is designed for ease of use, making it accessible to users without extensive statistical background.
2. **Handles Missing Data:** Prophet can handle missing data points and incorporate them in the forecasting process.
3. **Automatic Changepoints:** Prophet automatically detects changepoints in trends, reducing the need for manual intervention.
4. **Multiple Seasonalities:** It can accommodate multiple seasonal patterns within the data.
5. **Handles Outliers:** Prophet can account for outliers and dampen their influence on the forecast.
6. **Interpretability:** Components like trend, seasonality, and holiday effects are interpretable and can aid decision-making.
7. **Scalability:** Suitable for large datasets with the ability to handle many time series in parallel.
8. **Good Performance:** Prophet is effective for time series with strong seasonality and multiple patterns.

Cons of Using Prophet:

1. **Limited to Time Series:** Prophet is primarily designed for univariate time series data and might not handle complex interactions with external variables.
2. **Non-Adaptive Trend Changes:** While Prophet detects changepoints, it assumes the rate of change is constant, which might not hold for all scenarios.
3. **Assumed Seasonalities:** Prophet assumes yearly and weekly seasonalities by default; adjusting to more complex seasonality might require manual intervention.

4. **Tuning Required:** Despite automation, users might still need to experiment with parameters for optimal results.
5. **Limited to Positive Data:** Prophet does not handle negative or zero values in the input data.
6. **Long-Term Forecasting:** Can struggle with long-term forecasts due to potential missing patterns beyond historical data.

1.5. ERP and BI Tools

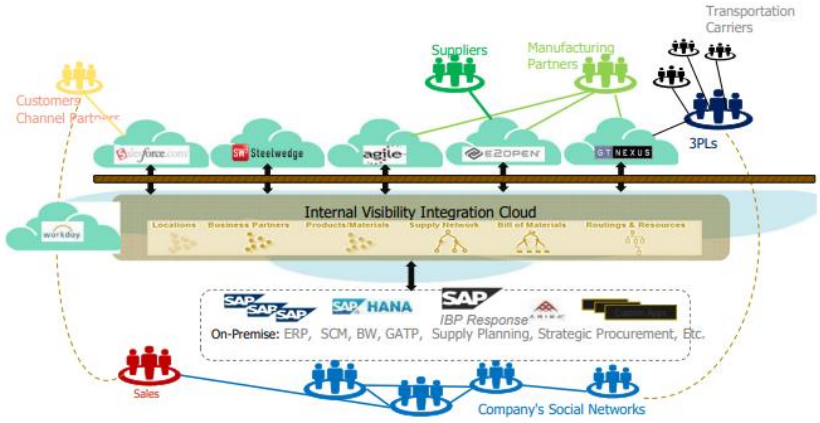


Figure 1.10 ERP and BI Tools in Supply Chain

In the 1.1.2 Paragraph we have seen that the supply chain achieved an optimal integration and collaboration among its main actors thanks to the Technology infrastructure, so now it is the moment to enter in detail. In this paragraph we will take into consideration the following technologies that irreversibly changes the way to intend the supply chain: Cloud Computing, ERP, Business Intelligence Tool

1.5.1. Cloud Computing

The digital transformation mentioned in the model has had a major acceleration with the advent of cloud computing technology, consisting in the hardware basis of overlying software technology structures.

The concept of cloud computing transcends traditional computing paradigms, offering a dynamic and flexible approach to data storage, processing, and application deployment. At its core, it involves the delivery of computing services—such as storage, processing power, and software—over the internet. Unlike conventional computing methods where resources are localized on physical servers or personal devices, cloud computing relies on remote servers hosted in data centers. Users access these resources on-demand, paying only for what they use, much like utility services. The cloud model encompasses three main service models:

1. **Infrastructure as a Service (IaaS):** Providing virtualized computing resources like servers, storage, and networking. Users can configure and manage these resources as per their requirements.
2. **Platform as a Service (PaaS):** Offering a platform that enables developers to build, deploy, and manage applications without concerning themselves with infrastructure management.
3. **Software as a Service (SaaS):** Delivering fully-fledged applications directly to users over the internet, eliminating the need for installation and maintenance.

Thanks to its characteristic and optimizer nature, it plays a pivotal role in shaping the digital era by offering agility, scalability, and cost-efficiency. Its impact extends to digital transformation, as organizations migrate from on-premises infrastructure to the cloud to harness technological advancements. By leveraging cloud services, businesses can innovate rapidly, deploy applications globally, and scale operations as needed. Moreover, cloud computing fosters sustainability too, reducing the need for physical hardware and energy consumption. It promotes a greener approach to technology by optimizing resource utilization and minimizing waste.

1.5.2. ERP

On the cloud infrastructure rely the ERP (Enterprise Resource Planning), that changes completely the way to manage transactional data. It is a comprehensive software solution designed to streamline and integrate various business processes across an organization into a single unified system. ERP systems provide a centralized repository of data, allowing different departments and functions to collaborate seamlessly, share information, and optimize operations. The goal of ERP is to enhance efficiency, transparency, and decision-making by providing real-time insights into the organization's performance. The most important softwares in the market are

1. **SAP ERP:** SAP offers a suite of ERP solutions that cater to various industries. SAP ERP integrates key business functions like finance, sales, procurement, and manufacturing.
2. **Oracle ERP Cloud:** Oracle's ERP Cloud provides a suite of applications for financial management, procurement, project management, and more.
3. **Microsoft Dynamics 365:** Microsoft's ERP solution covers financials, supply chain management, human resources, and customer relationship management.

In the context of supply chain planning, ERP solutions play a pivotal role in facilitating efficient communication and collaboration between different departments, enabling them to work cohesively and efficiently. Some of the key impacts of ERP usage in supply chain planning include:

1. **Data Integration:** ERP systems consolidate data from different departments into a centralized database, allowing real-time access to critical information. This leads to improved visibility across the supply chain, helping in making informed decisions.
2. **Demand Forecasting and Planning:** ERPs can analyze historical sales data to generate accurate demand forecasts. This aids organizations in optimizing inventory levels, production schedules, and procurement activities.
3. **Inventory Management:** ERP systems enable better inventory tracking, reducing instances of stockouts and overstocking. This enhances operational efficiency while reducing holding costs.
4. **Supplier Collaboration:** ERP systems facilitate efficient supplier collaboration by automating procurement processes, order tracking, and supplier performance evaluations.
5. **Cost Optimization:** By providing insights into cost drivers across the supply chain, ERPs help identify opportunities for cost reduction through process optimization and waste minimization.

Having the transactional data in a unique and certified database, accessible in real time, the business starts to need that this data should transform into knowledge or at least information. At this point Business Intelligence tool coming to solve this necessity

1.5.3. Business Intelligence Tool

Business Intelligence (BI) tools are instrumental in gathering, analyzing, transforming raw data into actionable insights and presenting complex datasets in a user-friendly manner, enabling organizations to make informed decisions and optimize various aspects of their operations. These tools facilitate data exploration, pattern identification, and the generation of meaningful reports and dashboards. BI tools enable organizations to gain a deep understanding of their operations, customer behaviors, and market trends, ultimately leading to better decision-making and strategic planning. This is the list of best in class Business intelligence tools:

1. **Tableau:** Tableau is renowned for its intuitive visual analytics capabilities. It empowers users to create interactive and dynamic dashboards, enabling them to uncover insights through visual exploration. With its user-friendly interface and robust data connectivity, Tableau helps organizations in supply chain planning to visualize demand patterns, track inventory levels, and optimize resource allocation.
2. **Power BI:** Microsoft Power BI offers powerful data visualization and sharing capabilities. It enables users to connect to various data sources, transform data, and create insightful reports and dashboards. In the supply chain realm, Power BI aids in tracking order fulfillment, monitoring supplier performance, and identifying potential bottlenecks.
3. **QlikView/Qlik Sense:** QlikView and Qlik Sense by Qlik provide associative data exploration and visualization capabilities. These tools allow users to explore data from different angles, fostering a deeper understanding of supply chain processes. They enable real-time insights into inventory levels, supplier relationships, and customer demands, enhancing decision-making.
4. **Domo:** Domo offers a cloud-based platform that combines data integration, visualization, and collaboration features. It facilitates real-time monitoring of supply chain metrics, such as lead times, order volumes, and inventory turnover. Domo's collaborative nature ensures that stakeholders across the organization are aligned on supply chain strategies.
5. **Sisense:** Sisense is known for its robust data analytics and visualization capabilities. It provides advanced data modeling and manipulation tools, enabling organizations to build complex supply chain analytics. Sisense aids in demand forecasting, inventory optimization, and scenario analysis.
6. **Relex:** RELEX is a supply chain software known for its exceptional forecasting capabilities. Powered by advanced machine learning, it delivers

precise demand predictions by analyzing historical data and market trends. This forecasting strength drives optimal inventory management, minimizing holding costs and addressing seasonal demand fluctuations. In supply chain planning, RELEX's impact is transformative, streamlining operations, preventing stockouts, and enhancing agility by enabling data-driven decisions.

7. **Blue Yonder:** Blue Yonder is a supply chain software renowned for its AI-driven forecasting prowess. With predictive analytics, it refines demand predictions using historical data, adapting to market changes for accurate forecasts. This strength enables precise inventory management, minimizing overstocking and stockouts. In supply chain planning, Blue Yonder's impact is significant, enhancing decision-making with real-time insights, optimizing resources, and boosting operational efficiency for a competitive edge.
8. **Anaplan:** Anaplan is a powerful software with strengths in forecasting. Its integrated platform facilitates accurate demand predictions by analyzing historical data and market trends. This forecasting prowess drives efficient inventory management, aligning supply with demand. Anaplan's impact on supply chain planning is remarkable, enabling data-driven decisions, real-time insights, and collaboration. It optimizes resource allocation, streamlines operations, and enhances agility for successful supply chain management.

The impact

From a visualization perspective:

1. **Data-driven Decision-Making:** BI tools enable supply chain managers to visualize complex data sets, facilitating data-driven decision-making. Interactive dashboards offer insights into inventory levels, demand patterns, and supplier performance.
2. **Real-time Monitoring:** Visualization tools provide real-time monitoring of key performance indicators (KPIs) across the supply chain. This empowers managers to proactively address issues and seize opportunities.
3. **Identifying Trends:** BI tools help in identifying trends and patterns within historical and real-time data. These insights aid in predicting demand fluctuations, enabling optimized inventory management.
4. **Operational Efficiency:** By visualizing supply chain data and identifying inefficiencies, bottlenecks, and opportunities for improvement, board software contributes to operational efficiency.

From an activities optimization perspective:

1. **Resource Allocation:** BI tools aid in optimizing resource allocation by providing insights into demand variability and production capacity. This leads to more efficient utilization of resources.
2. **Supplier Collaboration:** By analyzing supplier performance data, BI tools enable organizations to optimize supplier relationships and improve procurement processes.
3. **Risk Mitigation:** BI tools assist in identifying potential risks and disruptions in the supply chain. This enables proactive mitigation strategies and contingency planning.
4. **Process Automation:** Some BI tools support process automation within the supply chain, reducing manual interventions and increasing operational efficiency. Automation of routine tasks and workflows streamlines operations and minimizes errors
5. **Scenario Planning:** BI tool enables scenario planning by simulating different supply chain scenarios and assessing their impact on key performance indicators (KPIs). This aids in making informed decisions and devising effective strategies.
6. Predictive Analytics: The predictive analytics empower supply chain managers to identify trends, patterns, and anomalies within supply chain data. This insights-driven approach aids in proactive decision-making and improved resource allocation.

With this last paragraph we have complete the introductory part and now the reader has all the weapon to understand the next steps of the thesis

2 REAL CASES ANALYSIS

This second chapter of the thesis has the aim to analyze the AS- IS Status of the supply Chain. We are going to approach the problem in two main ways:

- The academic: through the selection of papers written by Scholars and Big 4 Managers, we will try to understand how the supply chain Planning works in our day.
- The practical: through an Interview submitted to RELEX and Blu Yonder Manager, we will try to understand which are min challenges that the companies faces in doing Planning and which are the proposed solutons

2.1. Academic

"To improve your supply chain, modernize your supply-chain IT", an useful article from Mckinsey written in 2022, helps us in describing the current situation. According to the article, the current state of supply-chain IT systems in many companies is characterized by the use of manual or outdated methods. For example, close to three-quarters of supply-chain functions rely on spreadsheets, while more than half use SAP Advanced Planning and Optimization (APO), a popular but antiquated supply-chain-planning application that SAP introduced in 1998 and will stop supporting in 2027. The portion of APO users in certain industries is even higher—75 to 80 percent of all the automotive, retail, and chemical companies surveyed. Despite the advantages that modern supply-chain-planning IT systems offer, an overwhelming majority of enterprises still use these manual or outdated methods.

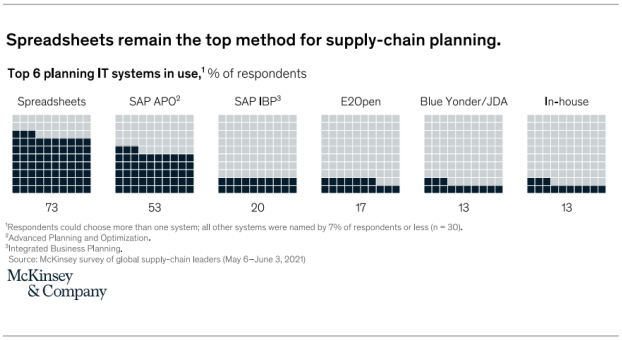


Figure 2.1 Survey's Result of "To improve your supply chain, modernize your supply-chain IT"

However, the article notes that supply-chain leaders know that current methods need to change and are taking steps in that direction. Of the executives surveyed, 90 percent plan to implement a new solution as AI, in the next five years, and 23 percent have already done so.

Figure 2.2 Survey's Result of "To improve your supply chain, modernize your supply-chain IT"

The same situation could be found in another article "Global Planning, Budgeting and Forecasting Survey", signed by Deloitte, where is highlighted that many organisations are still using outdated planning systems that lead to work duplication and process bottlenecks. These old ways of working are inefficient and ultimately cost organisations time and money. Lingering with these old ways of working points towards an inefficient utilisation of capital, and ultimately, costs organisations time and money.

Then it provides a to be representation where organisations have connected, cloud-based forecasting systems that link functions including finance, logistics,

commercial, and human resources together. This approach drives a connected planning process that provides meaningful insights in unison, rather than working off separate plans that don't provide meaningful insights. The increasing utilisation of scenario planning and real-time reporting, as well as a move towards predictive planning, are all driving the adoption of more sophisticated tools. Lastly, this article highlights that larger organisations are leading the way in moving from spreadsheet-based planning to sophisticated tools and technologies for planning, budgeting, and forecasting. Especially in organisations where the planning function is connected to all other functions, 51% of these organisations indicate a variance of less than 5% between actual vs. forecast. This highlights the benefits of using connected, cloud-based forecasting systems.

In another article, "Spreadsheets are Obsolete in the age of Big Data- What is Replacing them?", written by the Institute of Business Forecasting and Planning in 2020, it is deeply analyzed the cons in keep on working with spreadsheet and the pros in using advanced tool.

Commentato [GM9]: Rivedere impaginazione

Commentato [sg10R9]: Corretto

Limitations of spreadsheet highlighted by the article are:

- Not designed for online collaborative work
- Can only be edited by one user at a time
- Limited capacity for managing large amounts of data
- Limited ability to handle complex calculations and analysis
- Prone to errors and inconsistencies
- Lack of real-time data updates and integration with other systems
- Lack of scalability

On the opposite, new disruptive solutions powered by advanced analytics simplify data management, streamline common planning processes, and support sophisticated workflow creation and deployment. These solutions include demand-driven planning software, artificial intelligence, machine learning, and predictive analytics. These technologies offer real-time data updates, integration with other systems, and the ability to handle large amounts of data and complex calculations. Thanks to their characteristics they will bring this advantages::

- Increased efficiency and accuracy in demand planning and supply chain management
- Reduced costs through better inventory management and forecasting - Improved customer satisfaction through better product availability and delivery times

- Real-time data updates and integration with other systems
- Ability to handle large amounts of data and complex calculations
- Predictive analytics and machine learning capabilities for better forecasting and decision-making

This topic is remarked even more boldly by an article of IBM, "Spreadsheets are holding you back", that at the beginning reports some real cases in which the use of spreadsheets caused disasters as:

- In early 2019, a large Canadian firm in the emerging legal cannabis industry cited "spreadsheet error" as a cause of under-reporting earnings. The company's news release said "The correction was made due to a formula error in the spreadsheet supporting the yearto-date adjusted EBITDA loss calculation."
- In the spring of 2018, a major liquor and wine retailer in the UK lost 60 percent of its market value – £500 million – in a matter of weeks, due in part to an "arithmetic error" in a spreadsheet. The Times of London commented, "Not for the first time, human error with spreadsheets has led to disaster."

Then list a series of issues as:

- Failure of accuracy
    - Data integrity and transparency: Disconnected spreadsheets offer little in the way of data security or an audit trail to identify when, where or why changes were made, all of which lead to multiple versions of the truth. Consequently, confidence in the numbers is undermined. Poor version control can result in a consolidated plan based upon inaccurate or incomplete data or—owing to a mismatch of model structures—an inability to consolidate at all.
    - Collaboration: Successful business planning depends to a large extent on high levels of collaboration across teams. The greater the cross-departmental input, the greater the accuracy delivered in the plan. Due to error frequency and deployment difficulties, spreadsheet-based planning engenders a constrained, siloed process that represents only a small part of the organization.

- Failure of agility
    - Standardization: Spreadsheets, by design, are ad-hoc and ndividual. Email substitutes for systematic workflow. And without a guided, standard process, time is often wasted in "reinventing the wheel" and waiting for others to contribute and review. It is a laborious task for managers to check on the status of individual contributions and ensure they are submitted in a timely manner. The end result is a process that is limited by the pace of the slowest participant.
    - Speed: The business world is moving faster all the time. And to drive fast decision-making in this competitive environment you need to access and analyze large volumes of data and get answers quickly. A spreadsheet-based planning and analysis process does not allow organizations to alter plans, reforecast, or modify budgets in real time. Making changes in a large, complex spreadsheet requires both an inordinate amount of time and great care. The effort required to consolidate hundreds of spreadsheets can inhibit quick reaction to changes in markets or the actions of competitors.
    - Aggregation and application maintenance: Even if individual spreadsheets are error-free, the process of aggregating inputs from multiple users is a major undertaking. A single person or task group has to collect the numerous spreadsheets and consolidate them into a single version, trying to maintain files that may be linked together. If submitted models are not identical, the data will not consolidate correctly.
- Failure of scale
    - Size: When a spreadsheet's single data file is too large, it can make the program run very slowly. Spreadsheets are simply poor at dealing with large data volumes and merging multiple files. Users spend more time on data collection and verification than they do on analysis.
    - Granularity: Spreadsheets have a limited number of cells, which prevents users from including all the

granular data they need. If you cannot look at data at a precise enough level (ie you can only see product type, but not SKU), you will not be able accurately analyze the data and plan appropriately.

- Capacity: Once you hit a certain threshold, spreadsheets can no longer handle the amount of data and will crash. How many times have you lost your work or had your entire system freeze because of a spreadsheet with too many complex formulas?

Having clear which are the reasons for moving beyond spreadsheets and adopting new technologies, we need to understand which are the new trends. In doing this we are helped by an article written by Deloitte.

The article "What if your retail supply chain problem isn't your supply chain?- How the supply chain evolution

created retailer opportunity" discusses several innovation solutions and their impact on supply chain planning. Here are some examples:

- Advanced Planning Systems (APS): APS can automate supply chain planning for all but the most exceptional cases. The increase in computing power, on-premise or rented on demand from the cloud, the increasing maturity of optimization algorithms, and recent techniques such as machine learning make it possible to create a MPS, transport, tour, and shift plans, etc., without human effort in a quick manner. This can lead to faster and more accurate planning, as well as the ability to simulate many planning scenarios including stochastic influences.
- Big Data Techniques and Forecasting Analytics: The widespread use of sensors, tags, etc., make tracking, tracing, and collecting data very easy. This data can be gathered in data lakes and tapped using Big Data techniques. Hence, the enormous amount of data to calibrate and run those optimization techniques in a meaningful way is also available. An example of that could be use this amount of data as an input of advanced algorithms and machine learning techniques, embedded in forecasting analytics tools. They can help businesses to predict future demand and plan their supply chain accordingly, leading to more accurate and data-driven decision-making. Lastly, all this progresses can lead to

improved demand planning, better inventory management, more efficient production planning, and improved transportation planning.

- Continuous Planning and Scenario Analysis Tools: Continuous planning involves a cycle of gathering, updating, and enriching data to enhance the current set of plans based on new information. This can lead to more agile and responsive supply chain planning, as well as the ability to adapt to changing market conditions and customer demands.

Overall, these innovation solutions and trends can have a significant impact on supply chain planning by making it faster, more accurate, and more data-driven. They can also help businesses become more agile and responsive to changing market conditions and customer demands.

Lastly, we have to understand which are the difficulties in implementing that new technologies. According to the articles "To improve your supply chain, modernize your supply-chain IT", there are several difficulties that companies face when implementing new supply-chain-planning IT systems. These include:

- Lack of consensus on technical and process requirements: 45 percent of executives surveyed said that the biggest barrier to launching a project was a lack of consensus on a new system's technical and process requirements.
- Unrealistic expectations: 35 percent of executives surveyed said that the impact of a new planning system did not meet expectations
- Difficulty creating a compelling business case: 28 percent of executives surveyed said that they struggled to create a compelling business case to justify switching to a new system. 4. Implementation challenges: 60 percent of supply-chain-planning IT implementations take more time or money than expected or don't achieve anticipated business outcomes. Failings are indicators that processes are poorly designed or lack needed capabilities, or the change was poorly managed.

To overcome these difficulties, the article recommends incorporating three critical elements into the process of adop ting new supply-chain-planning IT systems:

- a forward-looking process design and change management. More in depth, it includes all the change-management components needed to get supply-chain planners and other

users of a new system involved in the implementation as early as possible to make the transition as smooth as possible

- well-defined vendor selection. The "to be" scenario would also involve well-defined vendor selection, with supply-chain leaders typically evaluating two potential vendors on average to ascertain which system best meets their specific planning challenges. Vendor selection is critical, and supply-chain leaders typically vet vendors using functional requirements, how a system integrates with existing supply-chain applications, and up-front and operating costs
- An implementation roadmap that prioritizes getting basic features right before adding more complicated use cases.
- Top management commitment. The article emphasizes the importance of commitment in successfully implementing new supply-chain-planning IT systems. The commitment of supply-chain leaders and other stakeholders is critical to ensuring that the implementation process goes smoothly and that the new system delivers the expected outcomes.
- Overall updates: , the "to be" scenario would involve reinforcing these elements with the appropriate organizational change, business process updates, and upskilling to maximize the sizable investment that an upgrade represents.

By following these best practices, companies can improve the outcomes of upgrade efforts and achieve anticipated business outcomes.

2.2. REAL CASES INTERVIEW

Until now, we have mainly had the corporate point of view, and this for sure helps us in having a clear point of which are the supply chain planning 's challenges but which are the solution? What about the companies who had the mission to innovate?

This was the reason why we prepare a list of 5 questions and submit to RELEX and Blu Yonder's Managers.

In the following paragraph we will report the questions and the relative answers

2.2.1. Introduce the company you work for. In addition describe the Sector of your customer

a. RELEX

RELEX Solutions is a cutting-edge technology company specializing in retail and supply chain optimization. Founded in 2005 Mikko Kärkkäinen, Johanna Småros, and Michael Falck, RELEX has established itself as a global leader in providing AI-driven solutions that empower organizations to streamline their supply chain operations, enhance demand forecasting, and improve inventory management. With a commitment to innovation and data-driven decision-making, RELEX has become a trusted partner for businesses seeking to thrive in the dynamic world of supply chain management. Its impact is perceived so disruptive that in 2019 received 200 million dollar investment from TCV, a fund that support disruptive companies like Relex and Netflix.

Its customers work mainly in the GDO-Grocery sector

Figure 2.3 Relex Presentation Slide: Who we are, Key points, Customer

b. Blu yonder

Blue Yonder, formerly known as JDA Software, is a prominent global software company specializing in supply chain management and retail optimization. With its advanced AI and machine learning capabilities, Blue Yonder empowers organizations to make smarter, data-driven decisions, enhancing their supply chain efficiency and customer satisfaction. It is important tom highlight that since 2015 Blue Yonder is consider stably present as a leader in all of Garnter's 4 Supply Chain

Magic Quadrants. Lastly, Blue Yonder has a series a customers that belongs to different sectors, symptoms of its versatility

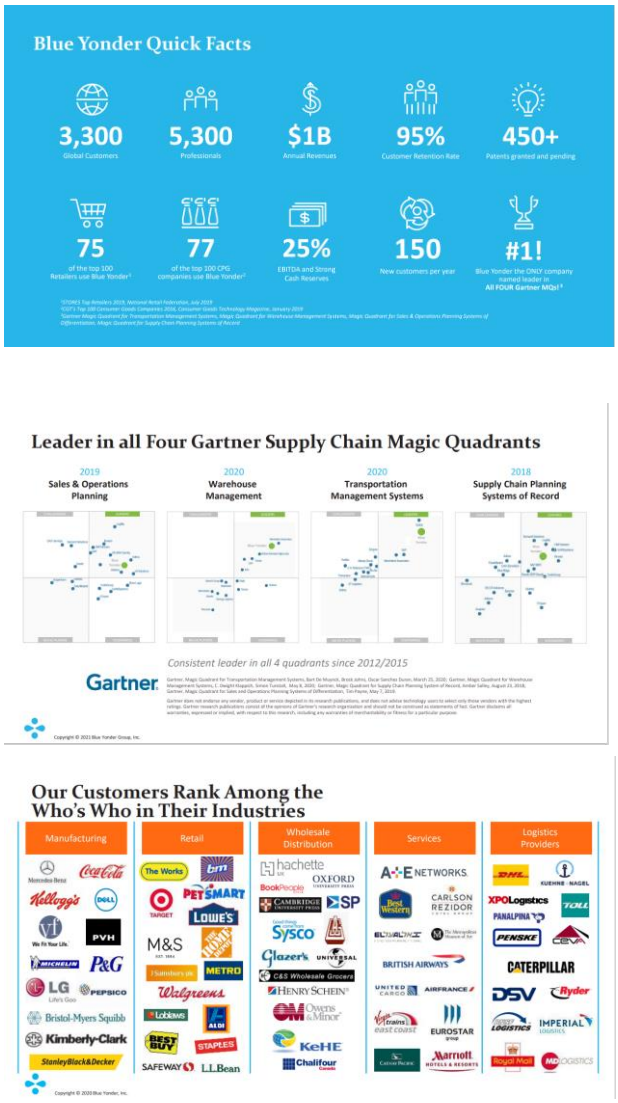


Figure 2.3: Blue Yonder Presentation Slides Who we are, Key points, Customer

2.2.2. Which are the main issues your customer has for Supply Planning Process?

c. Relex

The main issues are:

- Uncertainty: Retailers need to evolve, but cannot afford big mistakes
- Investment Policy: Every investment needs to Pay itself back in less than two years
- Amazon Effect/Uberization: 41% of grocery retailers feel helpless because of Amazon's massive resources
- Omnichannel Management
- Lack of Technology:
    - Most grocers' forecasting systems cannot factor in the impact of weekday-related variation, stock-outs, promotion attributes or weather effects.
    - Less than 25% have implemented forecast-driven automatic store replenishment
    - 60% have not yet integrated their store and DC replenishment.

d. Blue Yonder;

The main Issues are:

- Response time compression
- Increasing number of SKUs to manage
- Big data management
- Needs to Automate and Accelerate decisions 10%
- The Amazon effect Uberization
- Omnichannel Management
- Presence of New Technologies: Robotics, Real-time Sensors, IoT, Cognitive Computing

As We can see most of issues are shared between the two companies

2.2.3. Which are the characteristic of your solutions? Which Are the principle enablers?

e. Relex

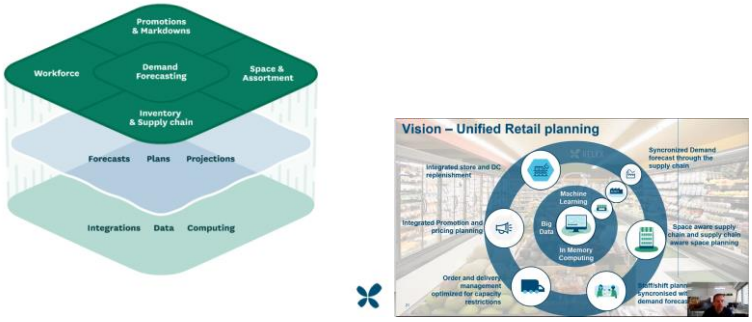


Figure 2.4: Relex Solution Architecture

Relex's one is a cloud solution with main goal is to provide a unique planning environment with the demand forecasting at the core center. The system will provide every day the forecasted sales for every product-location combination and consequently the orders to submit to the suppliers. It can be able to do that thanks to a solution composed by 3 differente layers:

- Data Gathering: In this first layer the ETL(Extraction, Tranfer and Load) Process takes place. The different data sources conveys the data to the Relex's Servers in the agreed format. The data will be cleaned and transformed thanks to the computing capabilities
- Scenario Analysis: In the second Layer the forecasts are calculated and Projected in the future on the base of preferred scenario/Plans Selected.
- Planning Decision: According to the forecast produced, the system provide suggestions on workforce, inventory, distribution and space Planning
-

It is clear that the main goal is having a unique forecast and a unique database that consistently supports every decision.

Relex recognizes as key enablers the

- The rapidly declining cost of data processing. In fact, the dramatic fall in memory cost has enabled the expansion of in-

memory computing capacity, which speeds up analytics several orders of magnitude. The Cost-effective data processing enables AI and ML algorithms developed decades ago to finally be used at retail-scale

- Data Processing Power. Their data processing platform is optimized for retail data and in-memory computation. Data-intensive processing is pushed down into the database, close to the data, in order to reduce data movement and the need to decompress data, for faster calculation and analysis.

In order to understand how e computing power is impactful an example will be provided. Consider a medium size retailers with 2.086 point of sales and 50.000 products per stores that requires a daily forecast with an horizon of 450 days and a daily frequency. The number of outputs required are 45 bilion and they must be calculated in a span time between 2 and 6 hours. This would be not possible without an adequate technology and forecasting system.

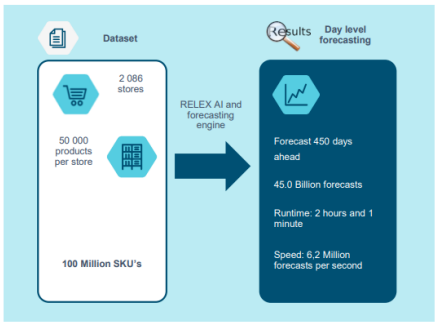


Figure 2.5 Relex' customers Improvements

f. Blue Yonder

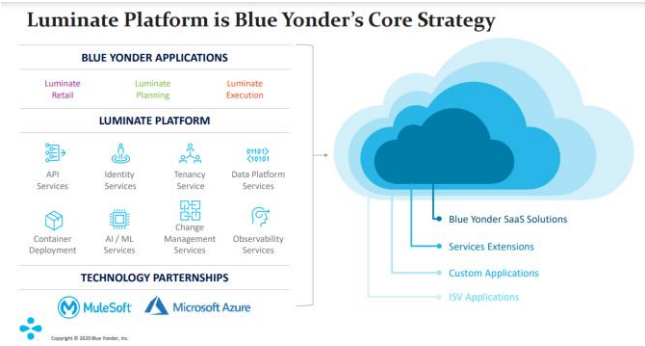


Figure 2.6 Blue Yonder Solution Architecture

Blue Yonder's one is a cloud solutions too with the aim to provide a digital twin of the supply chain. The Digital Twin serves as a dynamic and interconnected model that encompasses various components of the supply chain, including products, facilities, transportation, inventory, demand patterns, and even external factors such as market trends and regulatory changes. The significance of Digital Twins in supply chain management lies in their capacity to offer a predictive and prescriptive framework for decision-making. By simulating scenarios and evaluating potential outcomes, supply chain practitioners gain the ability to optimize processes, minimize risks, and seize opportunities. For instance, a Digital Twin can forecast potential disruptions, evaluate the impact of demand fluctuations, optimize inventory levels, and even enable predictive maintenance for machinery and assets.

About the solution architecture, also in this case we have a 3 tiers solutions. Blu Yonder is created upon a Microsoft Azure cloud computing platform that provide all the data processing power and memory storage it needs. The second stage contains

- ETL Process, that takes place through data platform , API services
- The Backend space where some application are developed or connected with the solution by the fact that the Platform is not closed

Lastly, the third stage consists in the Application's User Interface. Thanks to mthem the user run What If Analysis, investigate and eventually solve the issues highlighted by the system or have a look to the forecast suggested and do a root causes analysis.

Blu yonder as Relex highlights as a key enablers the Processing power for the same reasons.

2.2.4. Does your solution utilize Machine Learning or Artificial Intelligence? Could You provide some Use Cases?

g. Relex

The relex Solution works in this way:

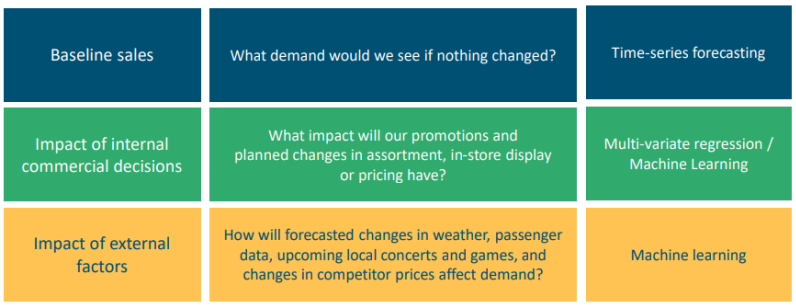


Figure 2.7 Relex Solution Scheme

Firstly they calculate the sales baseline, using Time Series Forecasting Algorithm. Then, evluates the impact of commercial decisions (like Promo). If the exploratory analysis brings good results, they are included in the forecast through Multi-variater regression or Machine Learning Algorithm. Lastly, the impact of externl factors are evaluated through machine learning algorithm. It is important to specify that they use the supervised learning algorithm and define their use pragmatic. In fact it is based simply on the following 5 steps

- Collecting data: Be it the raw data from excel, access, text files etc., this step (gathering past data) forms the foundation of the future learning. The better the variety, density and volume of relevant data, better the learning prospects for the machine becomes.
- Preparing the data: Any analytical process thrives on the quality of the data used. One needs to spend time determining the quality of data and then taking steps for fixing issues such as missing data and treatment of outliers. Exploratory analysis is perhaps one method to study the nuances of the data in details thereby burgeoning the nutritional content of the data.

- Training a model: This step involves choosing the appropriate algorithm and representation of data in the form of the model. The cleaned data is split into two parts – train and test (proportion depending on the prerequisites); the first part (training data) is used for developing the model. The second part (test data), is used as a reference.
- Evaluating the model: To test the accuracy, the second part of the data (holdout / test data) is used. This step determines the precision in the choice of the algorithm based on the outcome. A better test to check accuracy of model is to see its performance on data which was not used at all during model build.
- Improving the performance: This step might involve choosing a different model altogether or introducing more variables to augment the efficiency. That's why significant amount of time needs to be spent in data collection and preparation.

Then, they provide the impact of Promotion and weather based demand forecasting as an examples

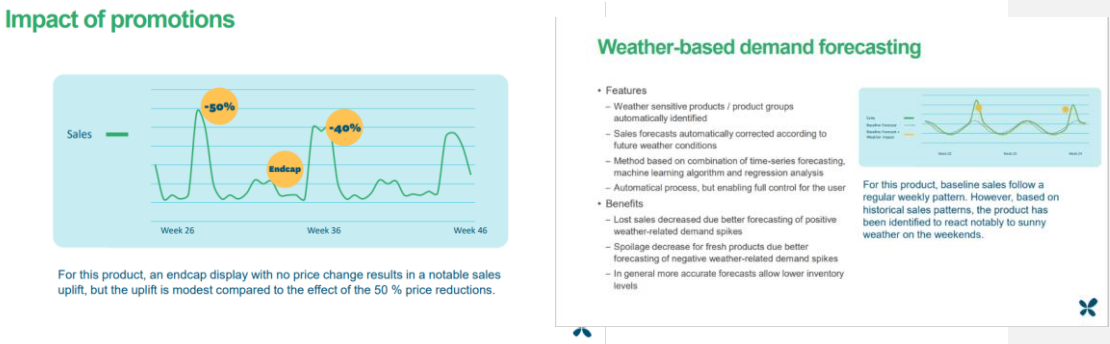
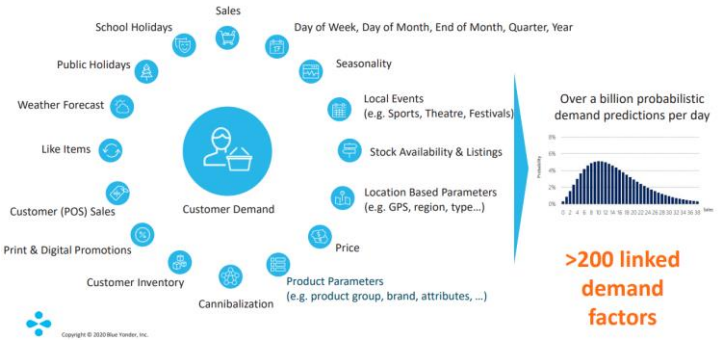


Figure 2.8 Relex Forecast Examples

h. Blu Yonder

The use of Machine Learning in the Blu Yonder solution is more complex. First of all, the solution uses unsupervised Learning algorithm for understanding which are the external factors has an important impact on the demand. Once, the most impactful external factors are selected, they are included in the forecasting algorithm.

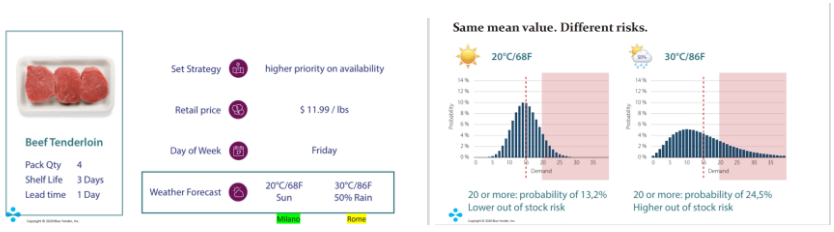


2.9 Blue Yonder Solution

Then, the algorithm will size the impact of each factor. It is nimportant because in a root causes analysis the user could analyze factor by factor. Lastly, the system gives as an output a probabilistic distribution of the forecast. The dinal values depens on the parameters set by the planner

2.10 Blue Yonder Solution

Also in this case an example is provided



2.11 Blue Yonder Forecast Example

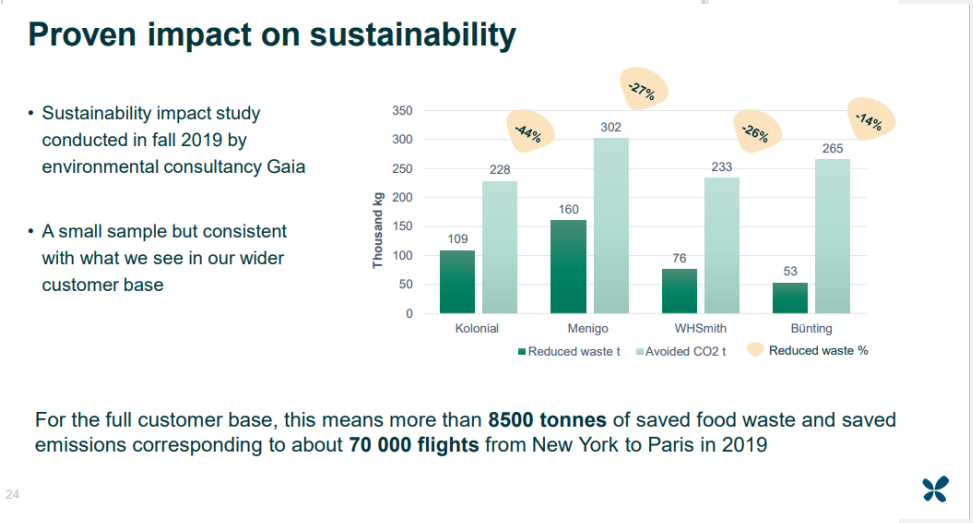
2.2.5. Which is the value added of your Platform? Do you have some Success case?

i. Relex

The value bring to its customers is twofold. From Process side, the main success consists in

- The semi- autonomous Planning through pragmatic AI at retail-scale for accuracy, speed and efficiency
- Adaptive Planning by unifying supply chains and core planning processes on an adaptable platform

Then about the most important financial results we have the following ones:

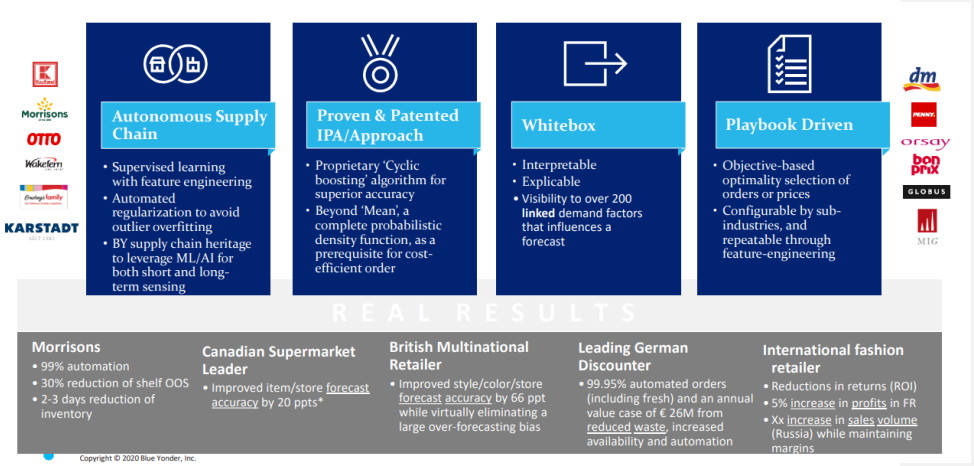


2.12 Relex' Key Results

j. Blu yonder

Also in this case, we have Process and Financial improvements

60-90% of Master Planner's time is spent to address problems in the very short term horizon Not enough time and effort spent to analyze root causes and effectiveness of past decisions Planners may have different understanding and ways to respond to a same business problem and hence lack common knowledge Not all decisions are made by a single planner, rather there is a need to collaborate with other functions like demand planners, production planners, logistics, CSR. Current methods are mostly through email and phone which results in no systematic corporate memory. Most of the analysis for resolution options and tradeoffs are done in offline tools after exporting data from multiple systems



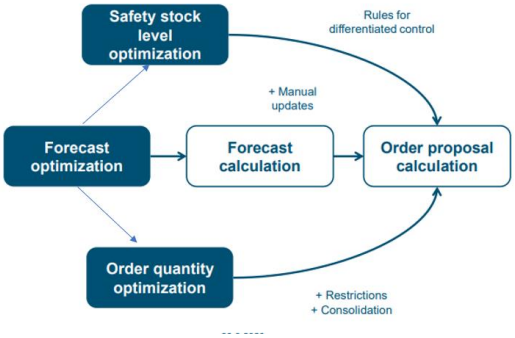
2.13 Blue Yonder Key Results

3 Research Questions

The two interviews were very useful, full of insights and complete the analysis on the supply chain planning. Both Managers have told that their solutions will be highly beneficial from the perspective of cost savings, but they didn't say anything

on which is the link between them and a good forecast. For sure, forecasting better leads to save but it is not enough to save 10 million dollars, and increase the gross profit of 23 million.

Relex helps us in answering to this question, sending this graph:



3.1 Solution's Supply Chain Planning Impact (Relex)

It looks like that the correct Order from the time and quantity perspctive depends on Forecast, Safety Stock and Order Quantity Optimization, where the las two depend directly from the first one, put at the heart of improvement.

Of course, this picture is not enough and we elaborate a Research Question:

- Which is the mathematical link between Demand Forecasting and Inventory Planning?
- How much the inventory management could improve using the leverage of Demand Forecasting ?

4 PROJECT CASE

In order to answer to the questions, I will quote a Project on which I directly work on. In the following paragraphs, the reader is going through: a brief introduction, useful to understand the environment; the situation found at the beginning with the relative performance; the Improvement Project deployed in all its phases; the results, after the test and the implementation.

Commentato [GM11]: Check English, many errors in this sentence:

In order to answer….

Commentato [sg12R11]: Corretto

4.1. INTRODUCTION:

4.1.1.1. EssilorLuxottica's E-commerce environment

The EssilorLuxottica's Ecommerce rely on a worldwide supply chain composed by 3 Production Sites (Italy, USA, China), 3 primary warehouses (Italy, Usa, China) and 4 secondary warehouses (UK, Brazil, Japan, India). EssilorLuxottica serves its clients through 35 banners (websites) offering more than 50 brands and 2.5 milion of single products.

This company is facing an extremely impacting integration of Planning process coming from new acquired banners. The integration has a very large scope: from way of working to the IT, Technology and Tools integration into a unique system.

Commentato [GM13]: Si intende brand?

Commentato [sg14R13]: Nono Banner è la definizione del Sito Web

4.1.1.2. Demand Planning and Stock Controlling Process

Each planner is responsible for the planning process of her banners and the relative countries served.
He or she is evaluated on two main KPIs:

- Forecast Error: How much the planner requires to have in stock (Cycle stock) for the her banner vs how much the website sells. It is calculated in this way:
  - WMAPE: $= \sum_i \frac{|Forecast - Demand|i}{|Demand|i}$, i= sku
  - BIAS= $= \frac{\sum Forecast - \sum Demand}{\sum Demand}$
- Out of Stock: How many skus in the assortment are available to be sold. It is calculated as follows for each Banner-serving warehouse combination $\frac{\#\ Active\ Skus\ with\ 0\ Stock}{\#Total\ of\ Active\ SKUs}$

Due to the integration aforementioned, not all the planners could rely on a best in class technology for doing their job.
In a standard situation the planner could count on:

- A large dataset, to which traffic data, Business Budget, Cleaned Historical Sales, Promotion Cluster, future prices belong
- Different forecasting tools that helps him to size the forecast and the safety stock.

On the opposite, the situation completely change if you are in charge for the planning of a not integrated banner. The next paragraph will explain deeply the difference among these two situations.

4.1.1.3. Integrated vs Not Integrated Banners

Two main definition that could help the readers:

- Integrated Banner: It means that the data load is 100% internal in the proprietary system and the planning process could be done on the tools. Furthermore a large and detailed set of data is available
- Not Integrated Banner: It means that the data load is not 100% internal in the proprietary system and the majority part of the planning process takes place on excel Spreadsheets.

From this definition is quite easy to understand that the integrated situation allows the access to more data (for example to the traffic one) and to a statistical forecast calculation engine that the second situation does not have.

4.2. STARTING POINT: THE AS WAS PERFORMANCES

The performances in the two kpis of integrated and not integrated banners highlight once more the huge differences between them.

Considering the Forecast Error:

- WMAPE:
  - Integrated: 50% on average
  - Not Integrated 120% on average
- BIAS:
  - Integrated: +12%
  - Not Integrated +32%

Deeply analising this KPI, we found out some patterns. First of all, the spread between Integrated and Not Integrated Banners is higher when we consider the region with high volume of sales but sensibly decrease in the region with low volume. The root causes consists in the fact that the low volume regions depend a lot from the knowledge of the planner and his/her sensitivity in the number. On the opposite. High volume region has some trend that could be intercepted only from the deeply data analysis.

Secondly, the stored traffic data, a cleaned historical sales time series, statistical promotion effect to which the not integrated banner have not access often explain the majority part of the forecast error's spread.

Thirdly, working on spreadsheets with reduced capacity to deeply analisys lead to approximations that at the end bring errors.

Considering the Out of Stock,

- Phisycal
    - Integrated Banners 1.7%
    - Not Integrated 3.5% (2% binternal production, 5.5% 3 Paties Product)
- Per view:
    - Integrated 2.8%
    - Not Integrated 6.2%

Also after having analyzed it, we found out two main root causes. The first one is the wrong forecast made for the cycle stock. Especially, the underestimation often brings to an increase of out of stock. The second one, even more related to this kpi, consist in the wrong sizing of Safety Stock, that is not able to overcome the supply or production issues.

Having clear the poor performances' root causes and the results of the studies from literature, now It is clear that some structural improvement must be undertaken for the Not Integrated Banners .

4.3. The Improvement Project

4.3.1. The Objective: Project Requirements

The Objective of this improvement Project is to build a quick, easy and user friendly solution that allows the not integrated banners' planners to exploit all the information and improve the related kpis. This solution will be used while the

Banners wait its integration and for that reason must not have a huge cost in Financial and time terms.

4.3.2. The Project GANTT

Taking into account the strict requirements expressed in terms of time and cost, we developed the following process, which is described in the following steps, when we were asked to act.

- Mapping Existing Procedure: This first phase will conduct a comprehensive analysis of the forecasting and demand planning process, going beyond the current KPI. During this phase, we will comprehend the Stakeholders, the mathematics underlying forecast estimation, and the information flows.
- Gap Analysis: This second phase aims to identify the process's primary pain points and the gaps that prevent it from being optimized.
- Solution Proposal: After analyzing the process, we will provide a comprehensive overview of the proposed solution. It would be explained from a process and mathematical standpoint.
- Phase of Testing: The solution will be tested with Region-Category-Month as the scope and SKU as the granularity.
- Results Analysis: The Process and Kpi-Financial results will be analyzed in great detail.
- Decision Phase : In this phase it would be taken the decision to extend solution for all the other Not Integrated Banners. It will be made in consideration of the solution's key results and the cost .

About the cost, effort and time we extimated:

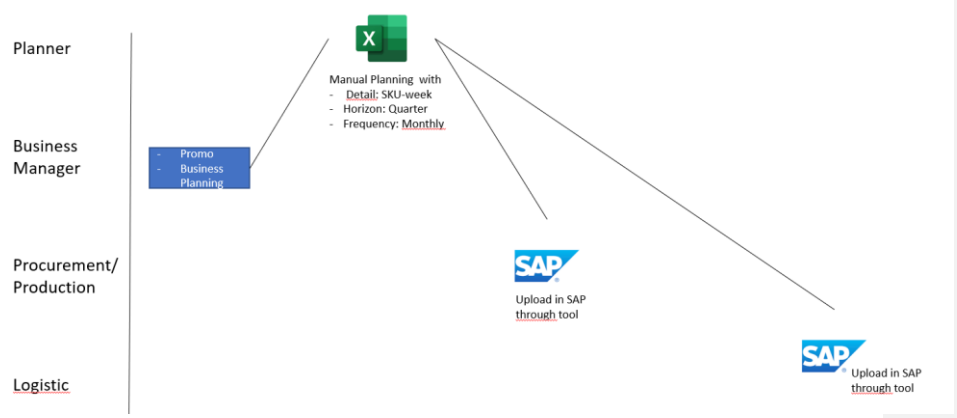
- 2 Person mapping the existing procedure and doing Gap Analysis at the 25% or his time for 2 months. It would cost $6.000.
- A team of 4 Person developing and testing the R Software Script, the connection Flow to Power BI and the Dashboards at 50% of their time for 3 months. It would cost $90.000.
- 1 Person in charge of Project and change management activities of the flows at 50% of his time during all the 5 months. It would cost $30.000

So in the end the total process cost is around $126.000 for 5 Months duration

4.3.3. The Mapping Process

The real first step of this process was mapping the planning and forecasting process of the not integrated banners and their data load for highlighting their pain points.

The first output of this step could be resumed in the scheme represented in the below picture



4.1 As Was Process

The process and data flow consists in the following steps:

a) The Business Manager Provides the business planning information for the different category of Products and eventually a list of promos that could affect/explain the sales.

b) The Planner uses the business information and combines them with the historical sales for producing the forecast of the amount of pieces sold for each SKUs for the next 3 months

c) The Excel will be uploaded in SAP and the requirement are passed to Procurement for the third Parties skus, to Production for the ones that are internally produced and, lastly, to the logistic in order to have a workload planning

Having clear the dataflow, we tried to map and standardize the formula through which the forecast and the Safety stock are calculated. Considering the Forecast:

$$\mathbf{Fcst=f}(\alpha, \boldsymbol{Demand\ Net\ Sales}, \boldsymbol{AUR}, \boldsymbol{Historical\ Sales}, \boldsymbol{Promo}) =$$

$$\alpha * \left(\frac{\boldsymbol{Input\ Demand\ Sales}}{\boldsymbol{AUR}}\right) + \ (1 - \alpha) * \boldsymbol{Last\ Year\ Sales} * \boldsymbol{Trend} + \boldsymbol{PromoEffect}$$

α = Trust in the Business Forecast [0,1]

The formula consists in the linear weighted average between the Business input data (Net Sales and AUR) and the Manual Forecast calculation base on Historical Sales data.

The weight is α, representing the level of trust in Business input data. Each Planner use a different coefficient, depending:

Commentato [GM15]: Pounded?

Commentato [sg16R15]: Corretto

Commentato [GM17]: Weight!

Commentato [sg18R17]: Lapsus! Corretto

- Firstly, on the relation with the business stakeholder, mainly based on the his/her capacity to explain the economic scenario
- Secondly, on the previous business and manual calculation forecast's error.

Then, Considering the Safety Stock:

SS= f(Forecast, γ) = (γ + δ)* Forecast

γ = Sales Potential (5%, 10%, 15%, 20%)

δ = Supply Risk (0-15%)

This formula relies on forecast and on two different factors:

- γ = Sales Factor. It is provided by Merchandise Team. It represent the sales potential. Higher γ means higher probability to have a sales peak.
- δ= Supply Risk. It is provided by production team for the internal produced skus and by the procurement team for the bought ones. It tries to explain the difficulties to have them in stock due to production/logistic delays

4.3.4. GAP Analysis

After having analyzed the performances and mapped the process, data flow and the calculations of the metrics, we compared it with the Integrated Banners and found out some gaps to be bridged. The main 3 are:

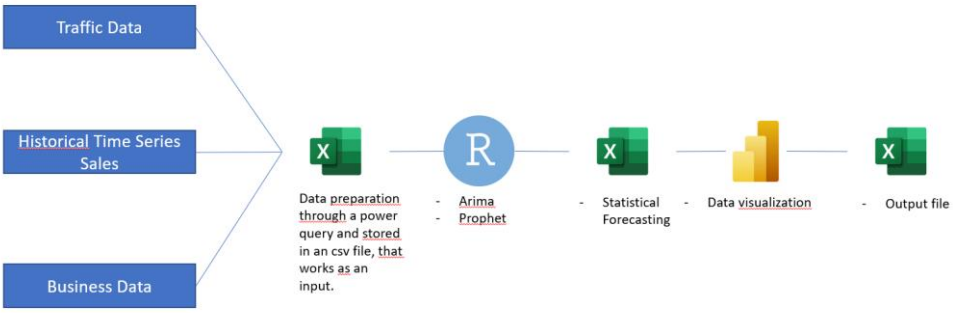
- Missing of a Statistical support. Infact, the not integrated Banners' planners completely miss an algorithm able to clean the data, find patterns or at least provide a statistical hint
- Limited Capacity to Analize data. Analyzing thousands of data's lines in excel should be complicated. An easy data analytics open source tool would improve the situation
- Usage of data: the data used consists only the 30% of the available ones

4.3.5. The Solution Proposed

It is clear from the requirements of the project and the gap analysis that a statistical support would be beneficial. It would be better if it will be calculated through open source analytics tools.

Knowing it, the solution was designed using R Software and Power BI as tools. In fact, this kind of solution would cover all 3 main pain points showed in the gap analysis and respect the time and costs constraints.

The tailored made quick solution is sum up as follows:

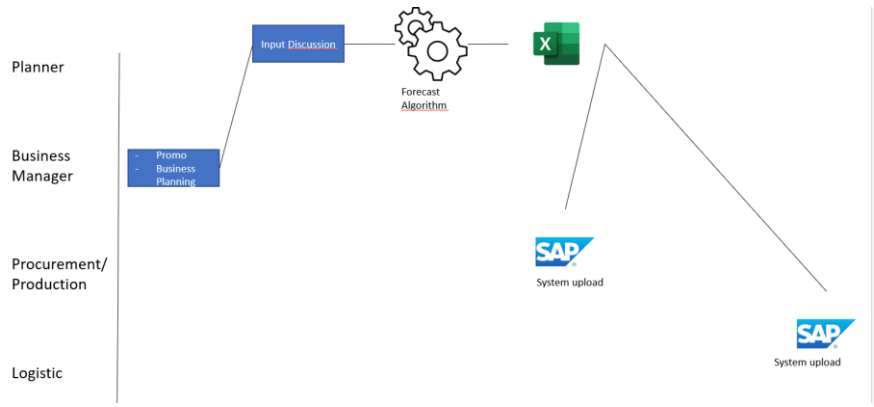


4.2 Technical Solution

The scheme could be summed up in the following phases Starting from the left:

- **Data Preparation:** automatic download of Traffic, Historical Sales and Business data's report, that through an excel query are aggregated into a csv
- **Data analysis:** The csv is read by the script written in the RStudio Software. The script relies on two main forecast algorithm: ARIMA and PROPHET. At the end of this step, the output consists in an excel files containing all the input data plus the statical forecasting provided by the Rstudio. This file works as input for the next step
- **Data Visualization:** All the data available at sku detail enter in a power BI. This step has a twofold function:
    - **Decision Making:** through the help of tailored made metrics, the planner has a drillable visualization of the data through which could take decision. At this step for example he/her could decide if a Prophet fits better than ARIMA or she needs a combination of the two algorithm
    - **Report Preparation:** Once the decisions are taken, the planner has available the downloadable report that will work as input for the final step.
- **Output:** At the end of the processs there would be an excel file containing the forecast at sku level. This file will be uploaded in the system

The solution that must be incorporated in the process. Starting from the Process, the "To Be" would be:



4.3 To be Process

1) Business Data Input: The Business team provide us the demand net sales and AUR forecasted for following 3 months
2) Input Discussion: Thanks to data Visualization, now the planner could re-discuss the input directly with the business team. A good clarification on the data provided for sure increase the level of trust on them.
3) Forecasting Engine: The validated business' data are combined with the other information as explained in the previous paragraph in order to provide the forecast
4) Data Upload: the forecast are uploaded in the system and available to Production,. Procurement and logistic team

About the forecast and safety stock calculation, the formula will be the following one:

- Forecast: = f(Validated Business Data, Historical Sales, Trend)= α*(Business Forecast)+ β *(Manual Forecast) + θ* Statistical Forecast
    - Statistical Forecast = (1-c) *Arima (Historical Sales, Traffic Data, Promo) + c*Prophet ((Historical Sales, Traffic Data, Promo)
    - Manual Forecast= Last year Sales* Trend + Promo Effect)
    - Business Forecast= $\frac{\textit{Input Demand Sales}}{\textit{AUR}}$
    - α=[0;1]; β=[0;1]; θ=[0;1]; c=[0;1]
    - α+ β+ θ= 1

- Safety Stock: SS f(Forecast, γ) = Min((γ * δ* Forecast);Upper Bound Statistical)

Also in this case, the calculation consists in a linear combination of different factors. It represents the simplest combination for a forecast without a satisfying history data. The Factors combined are:

- Statical forecast: It is linear combination of the two algorithm Arima and Prophet. The c, represents the trust in Prophet and it is estimated at the value of 50%. In this case we the tendency to overestimate of Prophet is limited by ARIMA that viceversa tend to underestimate.
- Business Input Data: this is the negotiated input coming from business
- Manual Forecast: It is calculated using historical sales

The α, β, θ represents the level of trust respectively on Business, Manual and Statistical forecast. This factors will change and be tuned with the usage of the algorithm .

Considering the Safety stock, it directly depends on the forecast and the input from Merchandise and Production/Procurement Department. The main change consists in applying an Upper Bound as maximum level of Stock accepted. It is calculated as the Upper Bound of Statistical Algorithm with the confidence set at 90%

Before concluding this paragraph is important to highlight two main points:

- The first one consists in how smoothly the new forecasting method enter in the process flow. In fact, the process hasn't changed at all, but the introduction of the tools allows the Planner to:
    - have a deeper knowledge of the data
    - foster the open discussion with the stakeholders (Business, procurement and Production teams) and create a stronger relationship with them
    - Have a Statistical support
- The second important element consists in the strictly connection between Forecast and Safety stock. Improving the first means also improve the second one.

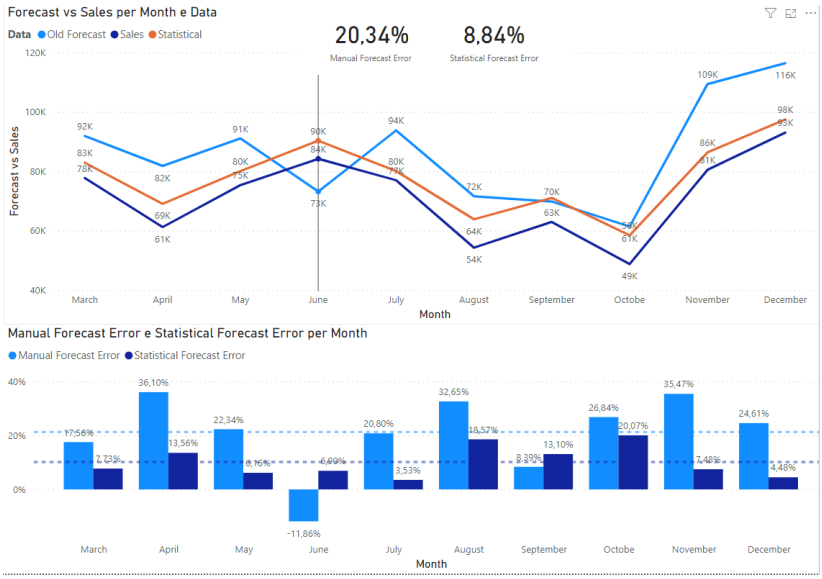
4.3.6. THE TEST PHASE

Once the solution was designed, we started to test the results and they were quite interesting.

Firstly, in order to have a better studies of sales curve we divided the observation into High volumes region (Emea, North America) and low volumes region (Latam, Apac). Then each region's sales dataset is divided by the 3 product categories as Sun, Optical and Contact lenses.

4.3.6.1. High volumes Sales Region

4.3.6.1.1. Frames' Sales



4.4 Frames' Forecasting Result for High Volume Region

Analysing the graphs, we could derive the following observations:

- The sales data have a lumpy curve characterized by peak periods (June, November and December) and low periods (august and October). The sales curve's behaviour Is explained by the presence of impacting promo and launches.
- The Statistical forecast curve's shape is highly more similar to the real sales' one than manual forecast's curve behaviour. Going deeply, the spread between the two forecasts curves took place in the peaks and lows..
- The statistical forecast given by the combination between Arima and Prophet algorithm with the same pound produces a better forecast because R software processes the historical and regressive data in a better way.
- Looking at the second graphs, we could derive that the statistical never underestimate the sales amount. This perfectly fits the project requirement

Having clear this general observation we would enter in the region-category Detail and comment the forecast performances:

Type
High Volumes

Region
NA

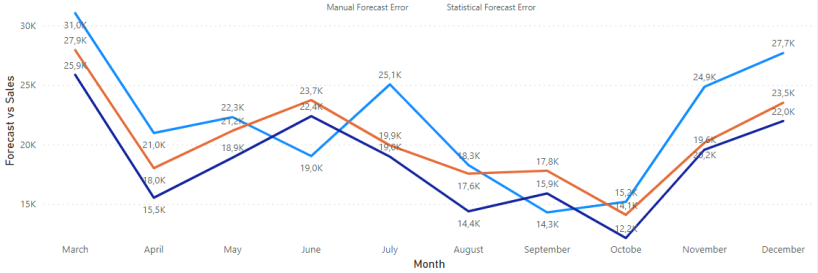
Product
Sun

Forecast vs Sales per Month e Data

Data ● Old Forecast ● Sales ● Statistical

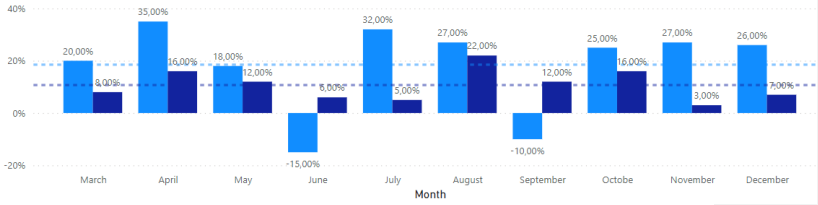
17,81%
Manual Forecast Error

9,83%
Statistical Forecast Error



Manual Forecast Error e Statistical Forecast Error per Month

● Manual Forecast Error ● Statistical Forecast Error



Type
High Volumes

Region
NA

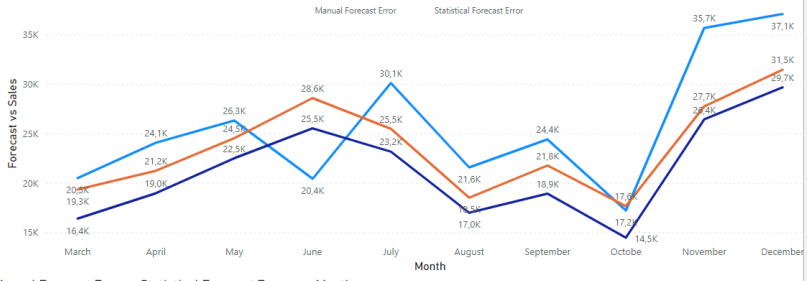
Product
Optical

Forecast vs Sales per Month e Data

Data ● Old Forecast ● Sales ● Statistical

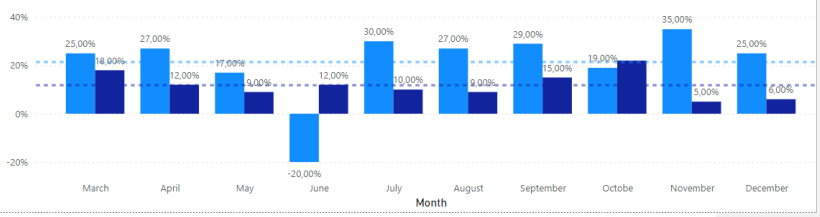
20,83%
Manual Forecast Error

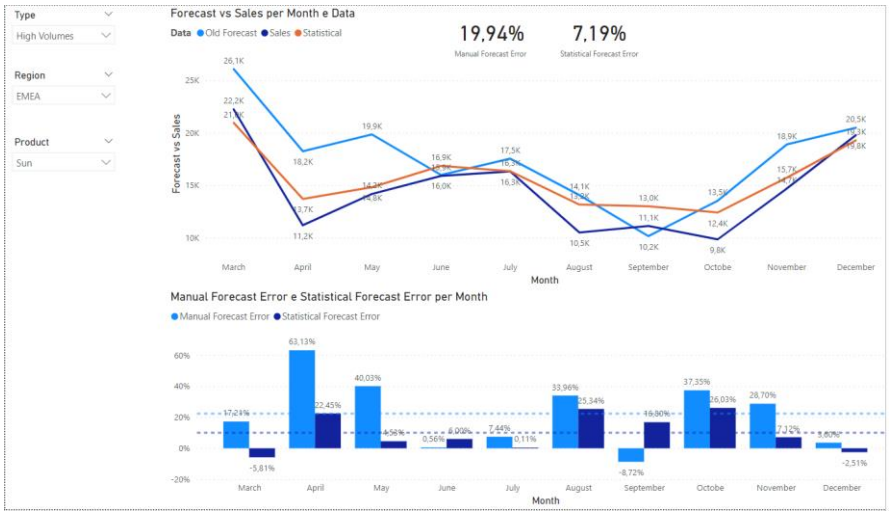
10,93%
Statistical Forecast Error

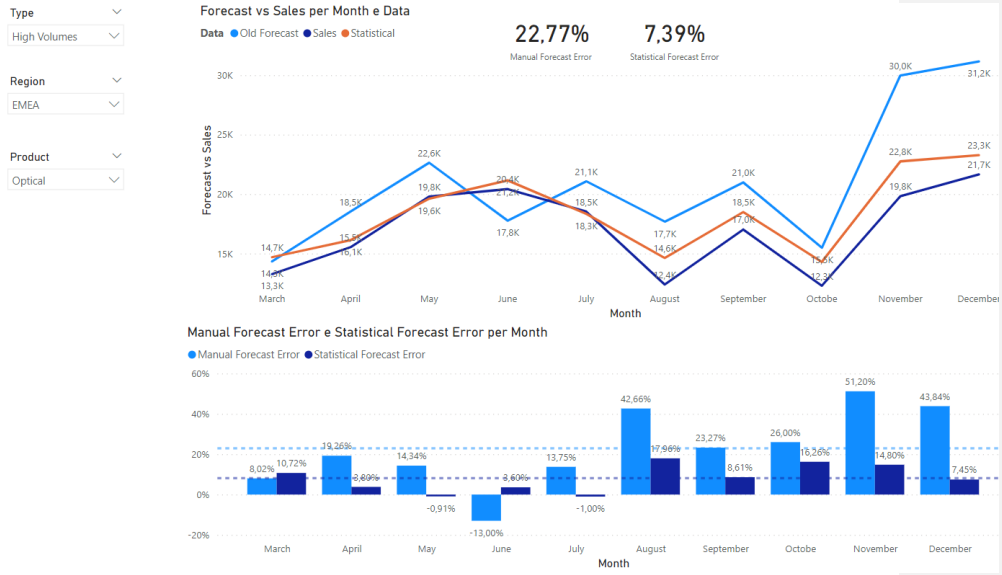


Manual Forecast Error e Statistical Forecast Error per Month

● Manual Forecast Error ● Statistical Forecast Error





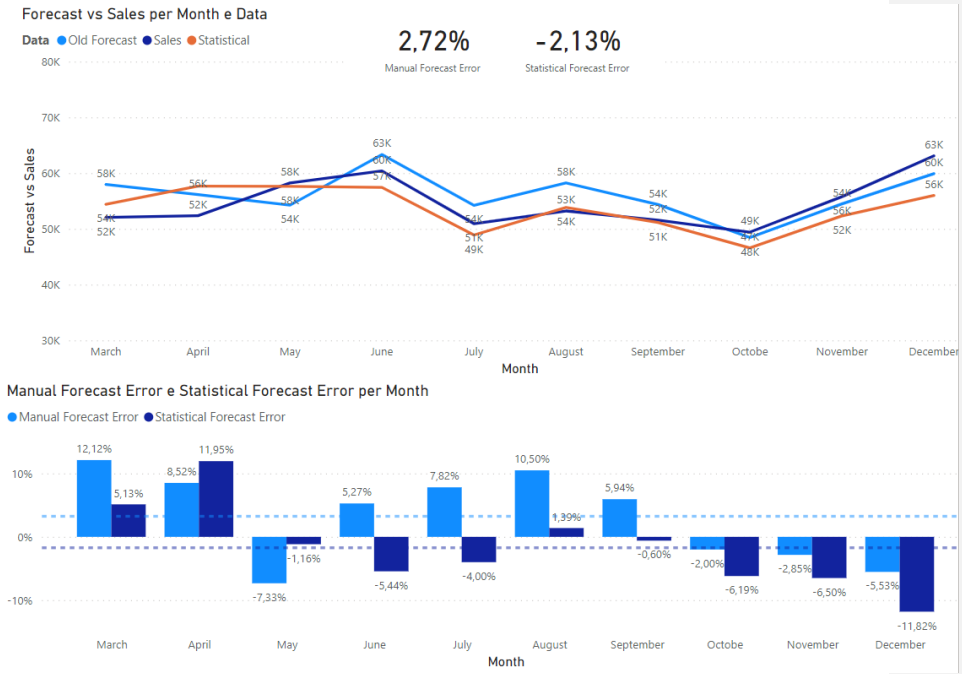


4.5 NA and EMEA's Forecasting Result for Sun and Optical Frames

- The Optical and sun sales curves', representing respectively the 30% and 26% of the entire business, have quite the same shape in the 2 different regions. In North America, July is slightly more impacting in sales performances due to business reasons related to geography and traditions.

- In all of the 4 cases the R software algorithm provide a better forecast than the manual one.
- Considering the Region-Category Detail, there are just few cases (June in Emea-Sun), where the manual forecast is better than the statistical one.
- As in the general case, the statistical forecast never underestimates the real sales, but at the contrary it always tends to overestimates.

4.3.6.1.2. Contact Lenses Sales



4.6 Forecasting Results for Contact Lenses

Analysing the Contact Lenses sales curve, we could observe:

- They have a more constant behaviour than frames, that it easier to predict. This is the reason behind the lower forecast error
- The statistical forecast is better than manual one in absolute numbers, but it tends to underestimate the sales, especially in the peak period. Going deeply, in the most important months as June, November and December the manual forecast is better than statistical one.

As previously done, now we would consider the region-Category detail:

Figure 4.7 Emea and NA's Contact Lenses Forecasting Results

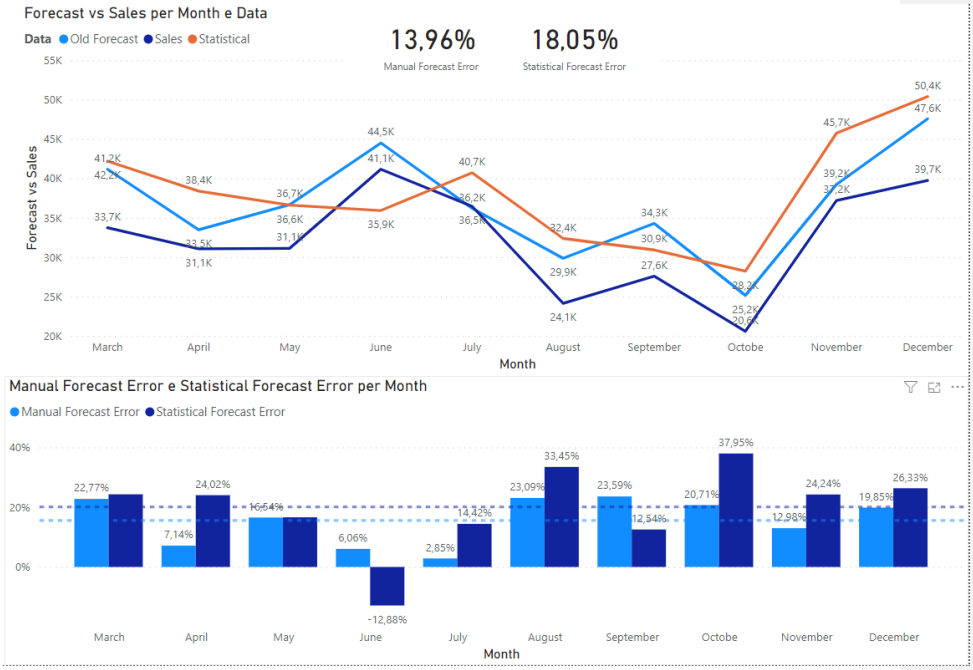
- In the two regions, the curves shape are quite the same. In the North American region, the sales curve's is flatter than in EMEA one. It could be the reason behind the lower forecast error.

- As in general view, the R software tends to underestimate the demand in both regions. Looking at the last 2 months in NA region, the manual forecast has an opposite behaviour respect to the statistical one

4.3.6.2. Low Volumes Region

In this paragraph we will consider the low volumes region

4.3.6.2.1. Frames' Sales

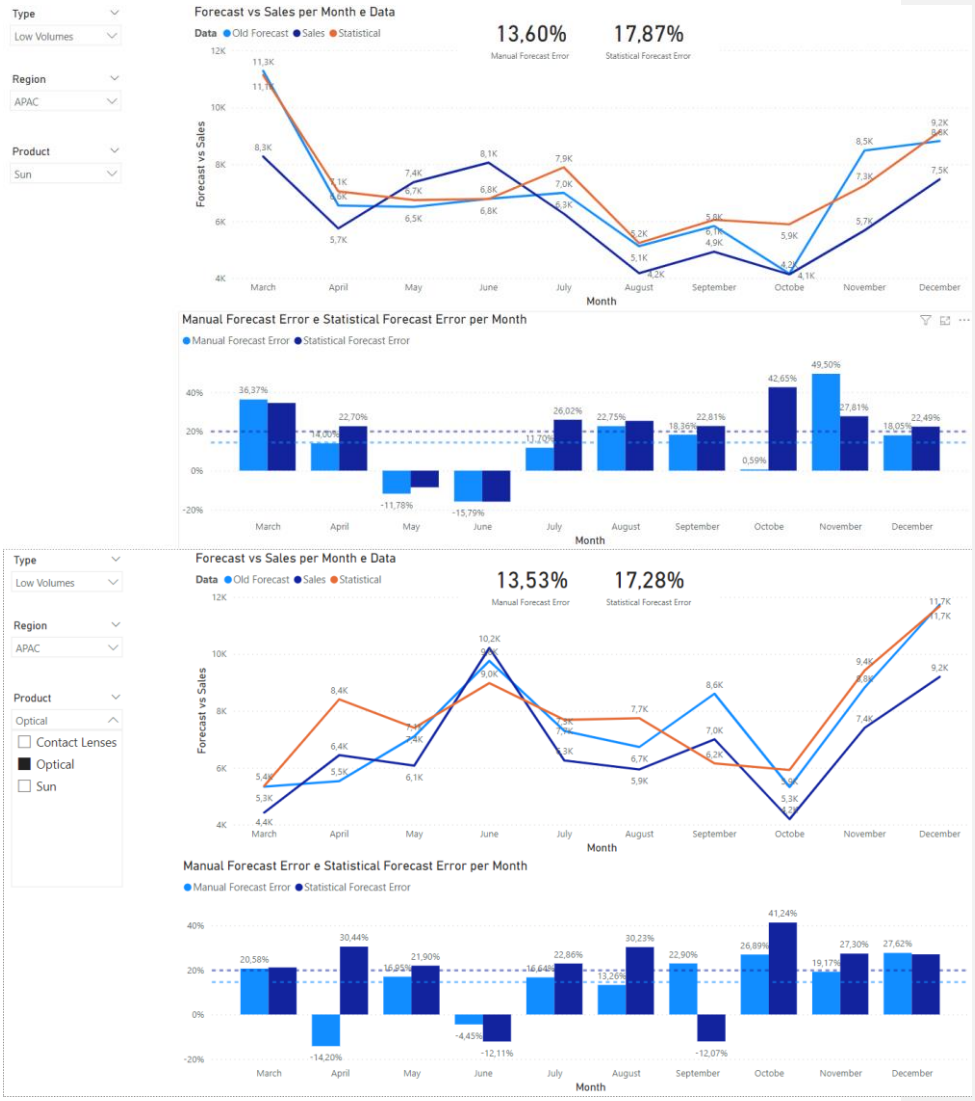


4.8 Low Volumes Region Forecasting results

- As in the high volume paragraph, we could notice that the sales data have a lumpy curve characterized by peak periods (June, November and December) and low periods (august and October). The sales curve's behaviour Is explained by the presence of impacting promo and launches.
- Differently from the high volume case, The Manual Forecast curve's shape fits better the sales' one

- The R software's forecast error is higher than the manual one. Going deeply, the forecast error attributed to the statistical forecast has the peak during the low sales periods
- The manual forecast never underestimates the demand sales

Considering the region-Product Category detail we will obtain the following graphs



4.9 Apac and Latam's Forecasting Result for Sun and Optical Frames

- The region-product sales curves' shape are very similar in the 2 regions with some exception in July and December.

- The Manual's forecast Error is lower than statistical one for all region-product combination.
- The demand's forecast in APAC is still driven by the hidden knowledge of the market and the planner's sensitivity. In fact the market is quite difficult to predict because it is growing and there is a lack of historical data

Commentato [GM19]: Questi numeri sono molto interessanti ma…. possono essere pubblicati? Non sono forse riservati?

Commentato [sg20R19]: A questo livello di Aggregazione e Citando il progetto come Consulenza ho ricevuto l'ok

4.3.7. Result analysis

After completing the test phase, we could summarize the key findings in this para graph. In order to be more clear we would separate into 2 main parts: Process Improvement and KPI and financial Improvements

4.3.7.1. Process Improvements

The key results are:

- Improved Communication: The improved calculation of demand forecasting facilitates communication throughout the demand management process. In actuality, the various enhancements, such as a more data-driven forecasting thanks to R Software and a better data visualization, facilitate communication among stakeholders, thereby directing the discussion towards the best decision for the company as a whole rather than for the department.
- Efficient and Smoother Process: This result is dual and partially related to the previous one. In fact, improved communication results in shorter meetings that require less time and effort, fewer misunderstandings, and quicker decisions. It is estimated that the time required to make a decision has been decreased by 20 percent, and the meetings concluded with greater consensus. Then, the dashboards that contain already-prepared data reduce the amount of time required to calculate forecasts by eight hours per week.
- Balancing the human knowledge and the technology: The tools are not miracle-makers, so it is crucial to understand how to utilize them and their limitations. The various findings from the Test Phase are one example. In the High Volume Region, the statistical forecast outperforms the manual forecast, whereas in the Low Volume Region, the opposite is true. As stated in the preceding paragraphs, the effect of the planner's sensitivity and inner knowledge on the outcomes is dependent on the extent to which they can influence the outcomes. This serves as a reminder that technological tools are merely a decision-making aid with varying levels of trust, and that a combination of inner and common knowledge will always yield the best results.

NA Forecast Error	Optical	Sun
Old Forecast Calculation	20.83%	17.81%
New Forecast Calculation	10.93%	9.83%

LATAM Forecast Error	Optical	Sun
Old Forecast Calculation	14.05%	14.66%
New Forecast Calculation	19.40%	17.64%

4.10 New vs Old Forecast Results

4.3.7.2. KPI and Financial Improvements

Every Project must have a Pay Back and it should be the minimum possible. This is why the most important and final key result is undoubtedly the improvement in kpis and the related financial improvements, which is the true engine of this project.

Commentato [GM21]: Chec English expression

Commentato [sg22R21]: Corretto

Taking into account the Forecast Errors, this process improved both BIAS and WMAPE.

- The Bias improved by 40 percentage points, from +32 to +18,5 percent, bringing the Not Integrated Banner closer to the average of 12 percent for Integrated banners. When we consider that we attained these results in a matter of months, they are astounding.
- The WMAPE was reduced from 120 percent to 90 percent, representing a reduction of 40 percent.

These improvements lead to a general reduction for pieces' demand, a more precise Production or Purchasing, reducing the excess for the slow movers and a more accurate sizing of the logistical resources rented from the third parties operators. The annual savings for a 25 million banner that sells 60k products accountable to these improvements are estimated to be $460,000.
The calculation of this results comes from:

- For the 80% sku produced internally the average industrial cost is $50 and for the rest external produced ones the average cost of buying is $70
- The banner sells from 3.500 to 5.000 pieces month
- Reducing the error by 14% it lowers the demand of an average of 700 pieces per month.
- The annual save is calculated as following:

  Annual Saving: (700*50*0.8+700*70*0.2)*12= $453.600

The remaining $6.400 are accountable to logistic and Transportation Services, accountable as $0.6 per pieces.

Furthermore, the forecast error enhancements are directly connect to the stock and has a positive effect on the Cycle and Safety Stock.
The Cycle inventory is better attributed to the 12k SKUs; consequently, the total quantity can be reduced without losing sales.
Then, with regards to the safety stock, its size is reduced by 10 percent passing from 25 to 15 percent. This improved capability to define th amount of safety stock is not only due to a more accurate forecast, but also because of a more accurate data-driven calculation and a better collaboration with the stakeholder in defining the Production/Procurement and Sales Potential Factors.
These improvements result in less immobilization of the stock reserved for the specifical banner, allowing other banners to use this stock to meet their demand.
The results are evident: the OOS dropped from 3.5 percent to 2.3 percent with a contestable reduction in stock.
Lastly, there are three financial benefits related to these improvements:

- Savings of approximately 50k for safety stock reduction.
- increased sales of the banner due to a 1 percent reduction in OOS, estimated at between 50k per year;
- Increased sales of the other banner due to a reduction in stock immobilization, estimated at approximately 200k.

In total the Savings are 553k euro and the sales increase is around 300k.

Commentato [GM23]: Impressive numbers

4.3.8. Implementation Decision

At the light of the key results, it is very simple to decide that the implementation must be extended to all the different not integrated banners.

The economic results are clear to a Pay Back Time of 6.5 Months: It would be 1.5 months if we not consider the implementation phase. How ever, they are just the iceberg's peak because we have to consider a more fluent, quick and optimized process in which the person are fully satisfied.

5 Conclusion

Coming to the conclusion of this thesis and before answering to the research question, we would like to briefly summarize the key findings and message this thesis will leave with the readers.

The first key message consists of the supply chain's inherent propensity to continue evolving and improving. This has been present 5 step model used to introduce the supply chain to the reader at the beginning of this thesis. Then it has continued with the Demand Management Topic and reached its full development during the real cases and the Thesis Project. This occurs because the supply chain is viewed as the connecting link between the various companies along the value chain, and it is under pressure to comply with the two aspects of effectiveness and efficiency: providing the highest quality product or service and operating as efficiently as possible by continually optimizing the production and information flow. Lastly in doing this we have not to forget how the focal company needs have visibility and to control all the tiers and actor along the chain, verifying that everything is compliant to laws otherwise some issues could happen. Famous was the Nike Scandal.

The second one is the dependence of Supply Chain Planning on Data Analysis and Business Intelligence Tools that is growing. This was made clear by academic findings, which revealed that not only have simple tools such as spreadsheets become completely obsolete to serve a very complex market, to predict a demand that is becoming ever more unstable, to respect even the smallest customer lead time, and to achieve the level of cost savings required to survive in a competitive environment, but also harmul. This is why the supply chain context necessitates complex structures to process massive amounts of data, analyze them, find actionable insights helpful to take decision as quickly as possible. The interviewed executive has identified this situation and prioritized the Supply Chain Digital transformation, including the Supply Chain Planning Tools and Specific Technological implementation. In addition, as the environment evolves, planners are increasingly expected to be familiar with business intelligence tools and to be able to manage, analyze, and extract insights from large and complex datasets. Significant interview differentiators at this stage include technical skills such as DAX, R, Python programming, or certification in the most important planning tools such as Anaplan, Blue Yonder, etc..

Thirdly, the importance of implementation management and the need for a high level of internal commitment and trusted vendors. This was highlighted in

particular during the interviews with Blu Yonder and Relex. The two managers emphasize not only the exceptional functionalities of the solution, but also their sector-specific expertise (Groceries for Relex), as well as their ability to design, support, and bring to fruition complex projects within the promised payback period. In actuality, they develop a scalable solution based on widely adopted technologies that can be easily integrated with the company's system. Then, in terms of support, they focused on customizing the solution so that it could accommodate each unique circumstance but also helps to manage it with best practises.

Lastly, answering to the two Researches Question we will consider the project case. About the first one:

How much the inventory management could improve using the leverage of Demand Forecasting Tool ?

Starting with the fact that for implementing a new forecasting tool we have to role out a complex process from the process. It requires analyzing the forecasting process and identifying the bottlenecks in the AS IS Process in order to resolve them. By relying on experienced consulting firms, they can assist us in redesigning a process that incorporates both the tool and best practices for maximizing its potential. In fact, the tool can be viewed as a vector of Best Practices from a process perspective.

In support of this, I provide the Project Case as an illustration. Once the data have been historicized and displayed in dedicated dashboards, stakeholders can engage in more fruitful discourse. This resulted in less friction during meetings and increased collaboration and trust among the various stakeholders, who were increasingly inclined to shift the discussion's focus to global process optimization rather than local.

Another example would be related to meeting deadlines for passing information due to the fact that the statical forecast runs at a predetermined frequency and requires input for operation. Thus, we create a supplier-customer relationship within the internal team, thereby enhancing the task management and the related time-effort.

Moreover, the pain points to be corrected are not only about effectiveness but also about efficiency: the tools allow for the existence of a single certified database on which analysis tasks are automated that reduce the time needed to perform tasks with little value, as data preparation, focusing on those of higher quality. This results in more attention to detail or an expansion of scope of ownership. Talking about the process, the meetings were not only more fruitful but also quicker. Scenario, What If and root-causes analysis at a high level of detail could be presented and together discussed during that meeting, making them at high data

intense. The data driven discussion drives to a more aware, agreed and quicker corrective actions, keeping the process always under control

About the second question, that is: Which is the mathematical link between Demand Forecasting and Inventory Planning?

We could respond that safety stocks account for forecast and logistical uncertainty.

Regarding the first section: the better the forecast algorithm can explain demand variability, the lower the safety stocks are. For a set of competing algorithms, responsiveness, time performance, and the ability to find correlations among massive amounts of data are three essential characteristics.

Regarding the first, it is a crucial characteristic when there is an irregular or seasonal demand and we want to capture all the peaks and valleys of the demand curve. The second is essential when we need to forecast with a high frequency or conduct multiple scenario analyses, requiring to have a different situation's point of views. Lastly, the ability to analyze large volumes of data, whether external or internal, in search of patterns or correlations would be extremely valuable, particularly in a constantly changing environment.

These characteristics help the demand planner determine not only whether the forecast should be increased or decreased, but also by how much. We want to highlight that the algorithms are always depending on the quality of the data provided and at this level will be always a support not a substitution of human decisions.

Example of what was stated in the previous lines is the Project: the algorithm performs better in forecasting the high volumes regions because we have a longer history, a larger and more accurated datasets. This happens thanks to its capacity of finding correlations able to identify relations between internal and esternal data and the responsiveness in being able to catch peak and lows, the statical forecast is performing pretty well . In low-volume regions with incomplete or inaccurate data, however, human forecasts outperform their statical counterparts.

Regarding logistical uncertainty, the historicization of production and Logistic lead time permits a thorough analysis. Then, the projection of data in useful dashboards and the ability to conduct scenario analysis enables the various actors to accurately quantify the and factors.

On the basis of data, the presence of statical confidence intervals permits the determination of the maximum size of the safety stock for each SKU. So again,

statistics assists us in determining the correct size that would otherwise be the subject of a local optimization decision.

6 Bibliography

6.1. Sources

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7 IMAGES