POLITECNICO DI TORINO

Corso di Laurea Magistrale in

Ingegneria della Produzione Industriale e dell'Innovazione Tecnologica

Tesi di Laurea Magistrale

SAP Advanced Planning and Optimisation:

a Demand Planning continuous process improvement Case

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ABSTRACT

This Master Thesis Project was developed within the ICT Department of a Multinational Company in the Food Industry.

Following the implementation of a common Enterprise Resource Planning (ERP) system provided by SAP, processes have been standardised across the globe and the data flow has been made seamless. The importance of Supply Chain Management has been acknowledged by the Company, that invested in the development of a SAP module called SAP Advanced Planning and Optimization (APO) in order to manage its Supply Chain processes.

Demand Planners have been provided with more advanced techniques to manage their day-to-day tasks.

Nonetheless, in the case of flavour Production Sites, demand planning remains an issue because of several reasons linked both with the nature of business and to difficulties to gather information from participants in the Supply Chain.

This Thesis focuses on the request for a Continuous Improvement Project for the Company's Flavour Sites in India and the suggested solution to improve their demand forecast accuracy.

The project aims to provide a method to the Demand Planners to perform a more accurate forecast on the SAP system that will be released to the Supply Planners. The new process proposed carries advantages and disadvantages that will be discussed in the second part of the Thesis.

The final part is dedicated to the Case Study analysis, measurement of the improvements, the findings and recommendation for the future.

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INTRODUCTION

The Company has successfully implemented the Enterprise Resource Planning (ERP) provided by SAP called ECC in most of the Region in which it operates across the globe.

The deployment of the SAP solutions is part of a project which aims to roll-out a global template to standardize practices across the business in order to increase the ability to control the processes and make data-driven decisions.

This Thesis focuses on a Supply Chain Continuous Improvement Project for the Flavour Sites in India. Flavour industry in India is growing at a fast pace and it is becoming a highly profitable business but at the same time a highly competitive environment, requiring low supply chain costs and a short time-to-market.

In order to meet customer's requirements and provide a high Service Level, Demand Management is a key process in the overall Supply Chain Management. Effective Demand Management is important to achieve balance between demand and supply, and it aims to be proactive in regard to customer demand by exploiting techniques to forecast it. In order to be able to provide an accurate forecast, it is important that the demand is kept as stable and as smooth as possible, as a volatile and intermittent demand is more difficult to predict.

Demand Planning is a part of Demand Management activities and it consists in a series of procedures to gather information about the customer demand from various sources in order to perform demand forecasting. The least the standard deviation from the real value, in other words the more the forecast is accurate, the more value is added to the final forecast and a positive knock-on impact is spread across the whole Company and across the whole Supply Chain. The importance of supply chain collaboration within the network will be highlighted in the first section.

Supply chain processes are modelled and managed in the Company using a module within SAP that is called SAP APO, Advanced Planning and Optimization. Demand Planning is performed in one of the sub-modules of SAP APO which is called SAP APO DP (Demand Planning).

Currently the functionality is almost not used at all by Demand Planners across the Company's Flavour sites. As a result, those that are currently using Demand Planning in APO are scoring low in terms of forecast accuracy. In India, the nature of business for flavours along with other business requirements have made the functionality difficult if not impossible to use. A detailed analysis on the root causes of the forecast inaccuracy will be performed also using some graphic methods such as fishbone diagram.

The aim of the thesis is to discuss the technical solution proposed by the ICT Supply Chain team for Indian Flavour sites within the SAP APO Demand Planning module and the implementation. The new demand forecast process will be performed at the aggregated level of semi-finished product (HALB), which will potentially improve forecast accuracy by overcoming some of the drawbacks of forecasting at finished produce level (FERT).

In the final part of the Thesis, an analysis of results is going to be performed as well as the measurement of the improvements achieved by the solution. The analysis for the Case Study will be performed on a sample of SKUs[1].

[1] Stock Keeping Unit

1 Demand Management and Demand Planning in the modern Supply Chain

1.1 Supply Chain Overview

A Supply Chain is a network that involves several independent companies that are tied together with the objective of delivering added value to the customer. As a matter of fact, the main objective for a supply chain is to fulfil the customer demand in the quantity, time and location required at the lowest cost possible.

In order to do that, Supply Chain Management encompasses several business processes such as demand planning, supply planning and sourcing, production, inventory management, warehousing and transportation.

Chopra and Meindl (2012) have provided this definition and summary of what supply chain is and what it does:

"A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves. Within each organization, such as a manufacturer, the supply chain includes all functions involved in receiving and filling a customer request. These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service."

As Stadtler (2005) points out, from this definition two perspectives emerge: the inter-organizational perspective and the intra-organizational perspective.

Under an intra-organizational perspective, decisions need to be taken in relation to the following supply chain processes:

- Sales order taking
- Backorder processing
- Forecasting and demand planning
- Distribution planning
- Replenishment
- Production planning and detailed scheduling

- Production execution
- Procurement

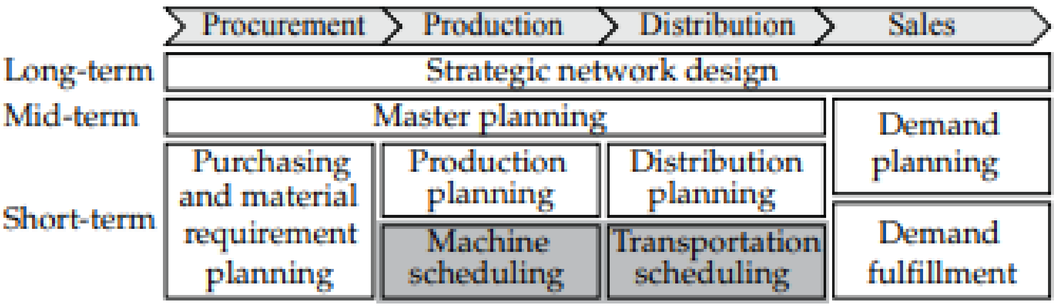


Figure 1 - Overview of Supply Chain internal processes

Under an inter-organizational perspective, a Company can be seen involved in a network of customers and suppliers that exchange materials and information among themselves.
A Supply Chain network can be modelled with nodes, representing the physical locations, and arcs, representing the connections between nodes also known as transportation lanes.

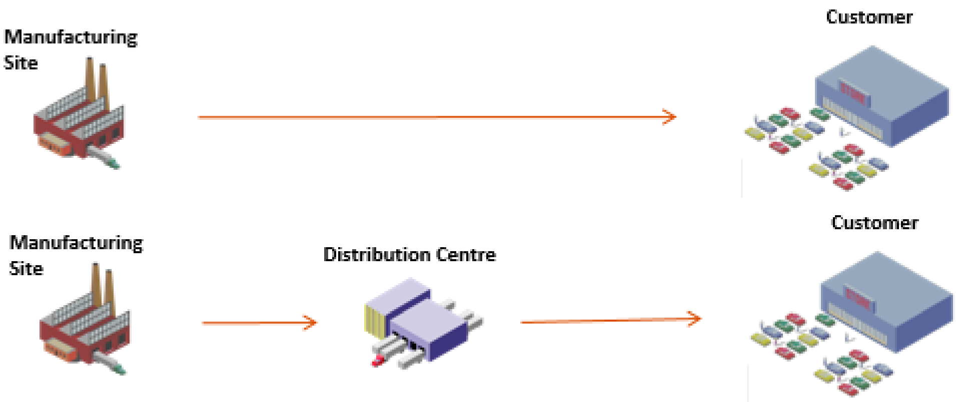


Figure 2 - Examples of simple Supply Chain Networks

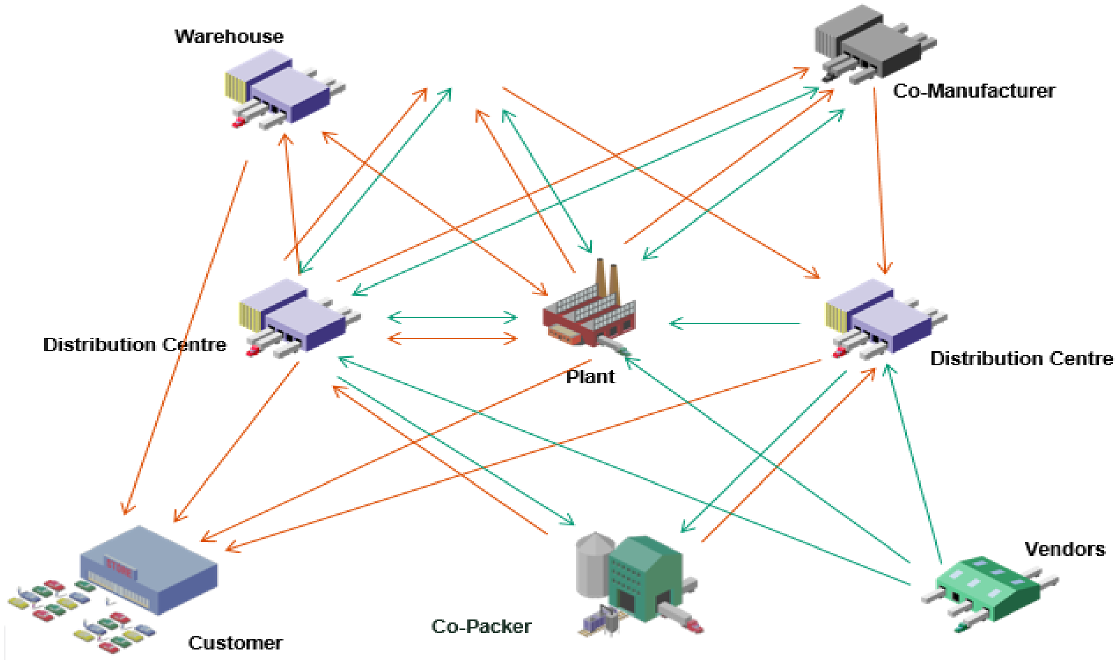
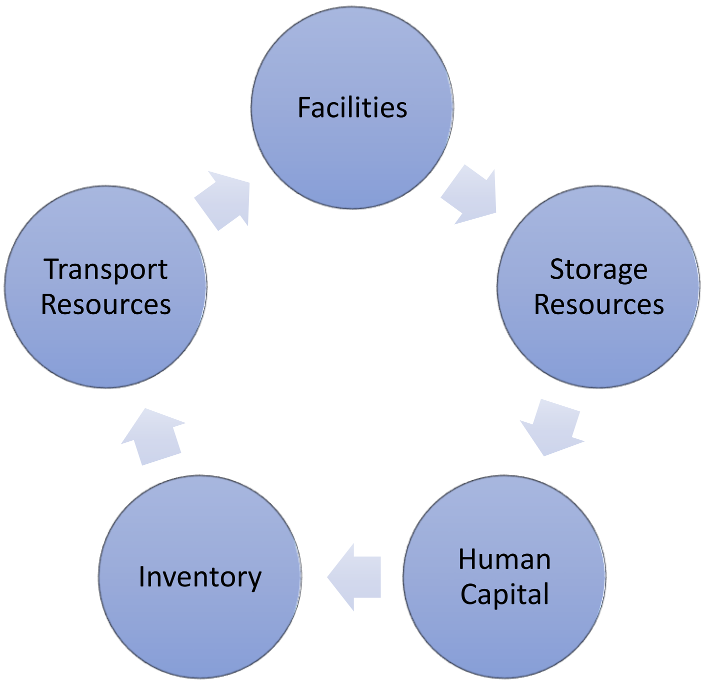


Figure 3 - Example of advanced Supply Chain Network

Overall, a supply chain network is comprehensive of:



The complexity is driven by the fact that the network could include several suppliers, each of them having several other suppliers and a number of customers and final customers.

Also, there can be third party logistics, marketing research providers or subcontractors and co-packers involved, that can provide goods or service to the company and ship it back to the Company or ship it directly to the customer. Within this network, material, information and money are exchanged between the several tiers.
In this further definition of supply chain provided by Simchi-Levi et al. (2008), it also emerges the relevance of another objective: cost reduction.
"*Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs while satisfying service level requirements.*"
As it is suggested by the definition itself, being involved in a network means that the efficiency and the cost reductions need to happen at an overall level.
Nonetheless, as the authors Khan, Zairi, Udin (2006) in the Business Process Journal point out, in the current era of dynamic competition production costs are not the only factors that could help organizations to gain and sustain competitive advantage. There are other important factors like a high customer's service levels, the product delivery time and its customization and quality that constitute a big part of the organization's competitiveness.

1.2 The new approach to the Supply Chain

The fundamental problem of Supply Chain is that often the delivery time of products to customer is supposed to be substantially shorter than the production time or lead time. Moreover, the dynamic environment causes the entire supply chain to continuously adapt to the changes and to new relationships between partners.
In order to remain competitive, the Supply Chain approach that is used in recent time is different from the one used in the past.
Before the focus was on optimizing certain logistic functions within the same Company, for example the transportation and the distribution structure.
The focus now shifted to grouping products with similar properties and taking all the processes per supply chain into account. Functions that in the traditional approach were not that close to

one another are now strongly linked together in the quest for transparency. This is the example of planning and execution, with sales planning and production planning bonded to give room to a significant optimisation that can potentially affect the entire value chain. The integration can happen not only intra-company but also inter-company.

Starting from the new Century, the development from competition between companies towards competition between highly specialized subjects within global supply chains started to emerge.

This brought to the development of concept such as risk management, change management and supply chain collaboration.

Because of the increased reliance on the network, it is impossible to think about a single Company's supply chain strategy. Each one of the members is affected by another Company's goals and decisions, and there is where the risk management emerges as a necessity.

In response to the need for tighter collaboration, several vendors have developed IT systems able to manage a organization's process complexity and risk. It is not only a matter of exchanging emails, nowadays key data flows between companies instantly across the globe within virtual collaborative environments.

1.3 Problems within ICT for Supply Chains

1.3.1 Integration

"Win together or lose together"

Integration allows to achieve more flexibility and responsiveness to customer needs, but at the same time, the attitude of working in silo is and prioritizing work within the department or the Company is still a preeminent way of working. This segregated style that does not allow open conversation forces each part involved to conduct the research by itself, doubling work, costing and inaccuracies. Also, the misalignment in performance objectives and measurements can create a barrier to integration.

The effects of this can be noticed in the quality of products and services, in greater costs, and other performance deterioration.

Another effect can be found in the firefighting way of working. The lack of visibility on other companies or department decision can bring problems at the surface only when it is too late and reactive actions need to be taken.

1.3.1.1 Poor data quality and poor data governance

The accuracy of data is vital for a company to plan and act accordingly. ERP systems usually assume that data are 100% accurate and they don't question it. Nonetheless, as a Research in 2014 conducted by Experian Data Quality highlights, 86% of the companies that have been interviewed admits that their data might be inaccurate in some way. The primary cause has been found in human error with 59%, while 31% of them stated the reason being poor internal department communication.

When data is not present, especially when dealing with Master Data, processes are slowed down as the ERP is able to recognise and raise an alert for the missing information. It then needs to be actioned by the data owner and that can be time consuming.

Moreover, bad data can also directly impact customer. The same research also shows brought to light that 75% of the business wasted 14% of the total revenue because of bad data quality issues.

This can also be driven by the legislative risk that poor data governance carries. The cost of auditing is much greater than the cost of having the data right in the first place.

1.3.2 Data Transparency

Data transparency represents the ability to access and work with data independently from the location in which they have been created or who has created it.

The problem of having information and data written down on paper or in an excel spreadsheet is an obstacle to the data transparency goal.

With a common IT system, data transparency can be achieved and can provide visibility on past and real time data about what is going on along the supply chain and allow means for a better management. It can give several information on phenomena, risks, their impact, and several other answers.

1.3.3 Bullwhip Effect

The Forrester effect also known as Bullwhip effect, consist in the increase of demand variability the further is the movement away from the final market. This phenomenon is recognised as being a big cause of inefficiencies.

The reason is because the information transferred in the form of order tends to be distorted, as suggested by the authors Padmanabhan, Lee and Whang (1997).

To provide an example to the reader, let us consider the case of supplying a good from the factory to the distribution centre, to the retailer and finally to the customer.

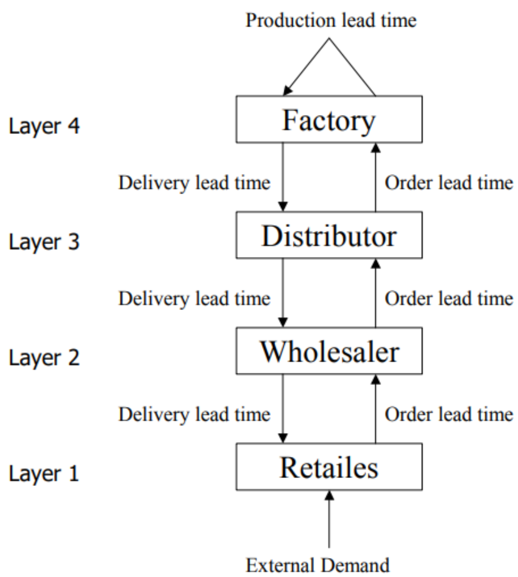


Figure 4 - Example of Supply Chain flow

The timeframe between placing the order and receiving the supply, the insecurity about the future orders of the partner on the demand side and the insecurity regarding the stock-outs at the partner on the supply side cause overreaction for the own orders, which destabilize the supply chain. The amplitude of the changes in the order quantity increases with the distance to the customer.

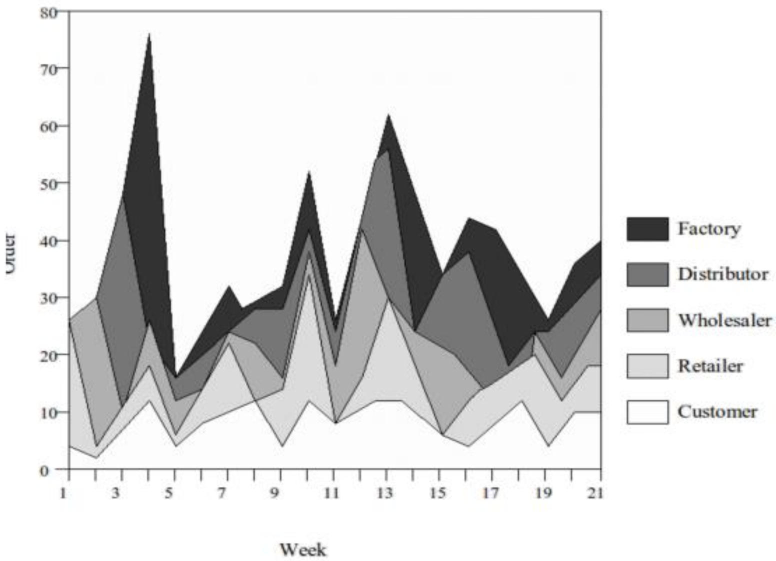


Figure 5 - The Result of Bullwhip Effect on Demand

Some of the **symptoms** of the Forrester effect are:

- Excess of inventory
- Unreliable demand forecast
- Intermittent capacity utilization
- Frequent changes of production plans
- Firefighting in order to provide the adequate service level

As it has been proved by several studies on the phenomenon, the main causes for the Bullwhip effect can be:

- **Price Fluctuation**: When general cost variation such as discounts upset the normal buying patterns, buyers try to take advantage of the lower costs by purchasing more stock than the actual needed.
- **Forward Ordering:** When buyers forecast scarcity of a good in the future, they decide to buy it in excess of some safety stock that will help them cover the period.
- **Batch Ordering:** Several are the reasons for the batch ordering. First of all, the purchasing plan for a Company can be released on a monthly base, therefore requiring purchasing goods to cover the needs for the month. Secondly, from the producer perspective, production can be made at a lower cost when in batches. This can provide benefits for the buyer in terms of costs. Moreover, fixed costs such as order costs or transport costs can force the buyer to purchase goods in a different quantity than the

solely necessary one. This can also be the case of the presence of minimum order quantity. The result will be in the presence of big orders separated by a long time of absence of demand

- **Demand Forecast bias**: The demand forecast result determines the stock levels thought a set of techniques that involve statistical models. They are generally based on sales orders from the end customers. When the retailer generates its forecast he also takes into account the stock and safety stock he wants to safely cover the future demand fluctuation. Once the forecast is completed, it is then passed on to the supplier and so on. The supplier updates his forecast based on the data provided and it enriches it with its own forecast. But this data takes now into account also a stock from the first member of the supply chain that is not real demand.

1.3.4 How to mitigate the Bullwhip effect though effective Demand Management

The primary task of Demand Management is to balance out the requirements coming from customers with the supply chain capabilities. This involves a series of processes in order to allow the Company to be proactive in regard to demand and anticipation of customer needs.

Demand Management is important as it will drive the supply plan, purchasing plan, capacity plan and the overall asset utilisation. It drives the budgeting plan and it aims to reduce time to market by cutting down the time for the procurement of materials.

Demand Management focuses on ways to reduce demand variability so that the forecast is consistent, costs are reduced and at the same time, level of service is maintained and enhanced.

The type of variability that is customer driven and it is difficult to eliminate. Nevertheless, it can be smoothened by taking advantage of analytics tools, collaborative planning, market intelligence, statistical methods, artificial intelligence. Avoiding policies such as frequent promotions, assessing if batches and minimum order quantities can be revised are just some potential solutions, keeping in mind that this will affect negatively other departments and economies of scales might not be achieved.

As it has been possible to notice, an effective Demand Management is also a tool to minimise the bullwhip effect.

The ineffectiveness of the Demand Management can be evident when the customer demand is erratic or volatile, in other words when the demand moves quickly and unpredictably, making it difficult for the business to manage the complexity throughout the overall Supply Chain.
A volatile demand is represented by a graph where the demand amplitude is significant and there are evident peaks and troughs.

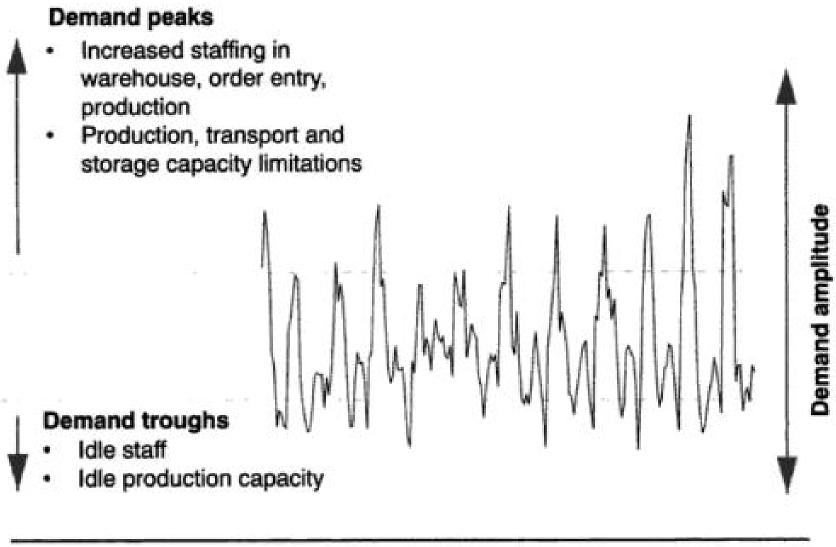


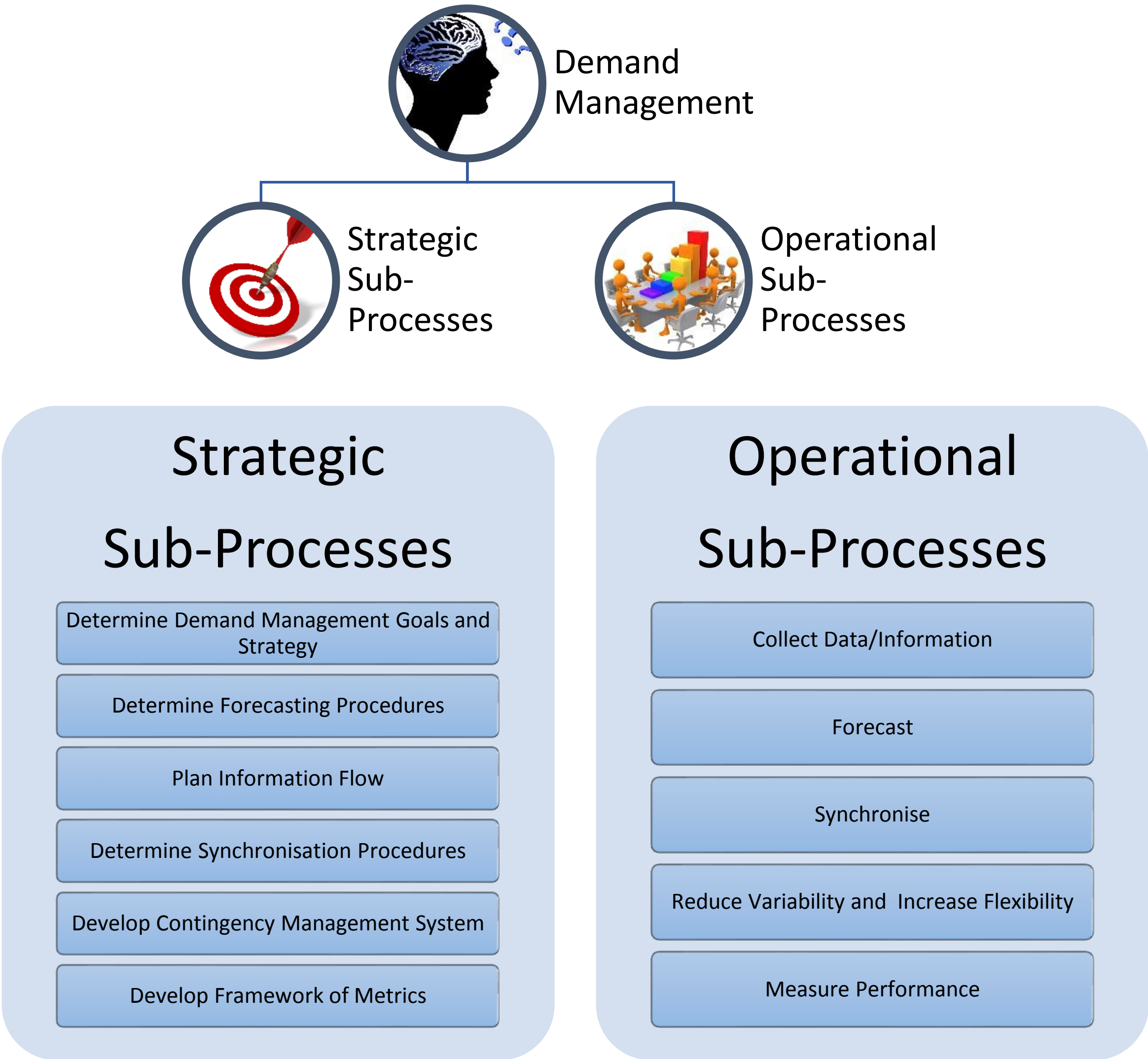
Figure 6 - Demand Amplitude

As Gattorna (2016) highlights, an increase in the demand amplitude can cause not only higher costs but also:

- Uncertainty, for example in relation to price fluctuation, risk of stock out. This makes difficult planning especially for the product with a long production cycle
- Reliance on accurate and timely information to get more visibility on the status of the overall chain
- Inventory to cover volatility risk and the linked risk of obsolescence
- Increased reliance on production capabilities despite the fact that the information given to manufacturing are less accurate

1.3.5 Strategic and Operational Elements in Demand Management

In order to describe the processes within Demand Management in detail, the framework suggested by Croxton, Garcia-Dastugue, Lambert and Rogers has been adopted.



1.3.5.1 The strategic Demand Management Process

Within this perspective, the Company decides what IT system will use for the Demand Management processes and how this will be integrated with other Companies participant at the supply chain, how processes will be modelled with the system and what benefits to expect from it.

1.3.5.1.1 Determine Demand Management Goals and Strategy

The goals of Demand Management need to be first aligned with the overall Company strategy. This implies a broader understanding of the customer needs, the manufacturing processes, capabilities and bottlenecks, the facilities and the resources and the whole supply chain network. This is done with the purpose of determining focus and goals for the Demand Management process.

1.3.5.1.2 Determine Forecast Procedure

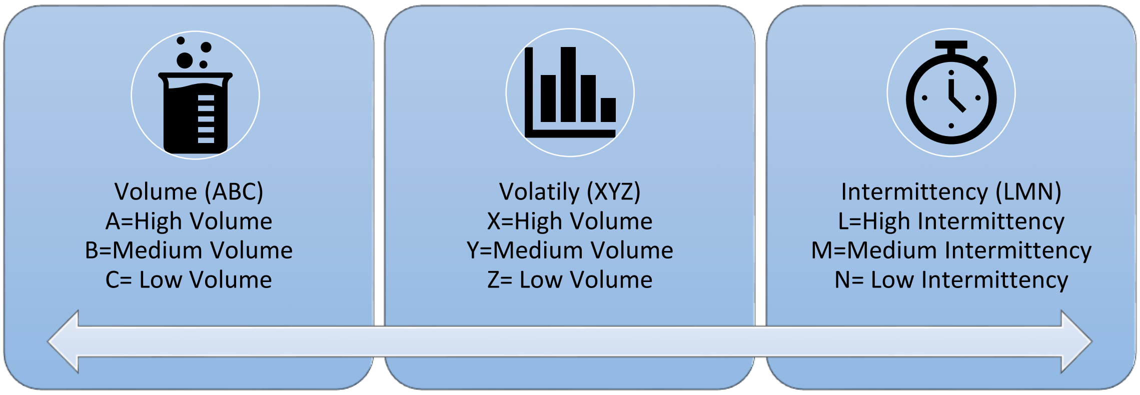
Forecasting is the critical part for the Demand Management processes. This involves deciding the level of the forecast and the time frames, the aggregation and disaggregation levels, but also the source of data and the forecasting methods and models that will be utilised.

These decisions need to be driven by management, that has to keep the different forecasting procedures as consistent as possible not to lose control over the process.

In order to determine the source of data, several sources can be considered. History of sales, existing sales order, marketing intelligence, collaborative forecast from other Companies, promotion plans.

The design of the forecast process and the model to forecast is the following steps.

In order to make decision about the correct forecast approach, one of the most popular criteria is to group products based on the demand variability, volume and intermittency. These are also known as ABC, LMN, XYZ analysis.



ABC classification in based on the proven fact that, for most of the Companies, only 20% of the SKU in their catalogue account for 80% of the total volume of sales. This kind of SKUs are considered as "A" SKUs in the classification and the balance of the "B" and "C" only drive 20% of the sales. Being able for a business to focus on this "A" SKUs mainly by using a stricter control on them and tighter thresholds is a great advantage.

ABC/XYZ – This classifies volume in terms of ABC classification and then calculates the co-efficient of variation in terms of XYZ, meaning how volatile/erratic are the order volumes when ordered.

- X if Is there relatively little variation in volumes ordered
- Y if there is volatility in the volumes ordered
- Z if the volumes are erratic, very difficult to predict

XYZ/LMN – This analysis classifies the order pattern (LMN) for an item, the co-efficient of intermittence, using the XYZ classification as an input. It is looking at how regular an item is ordered but also considers the volume variability.

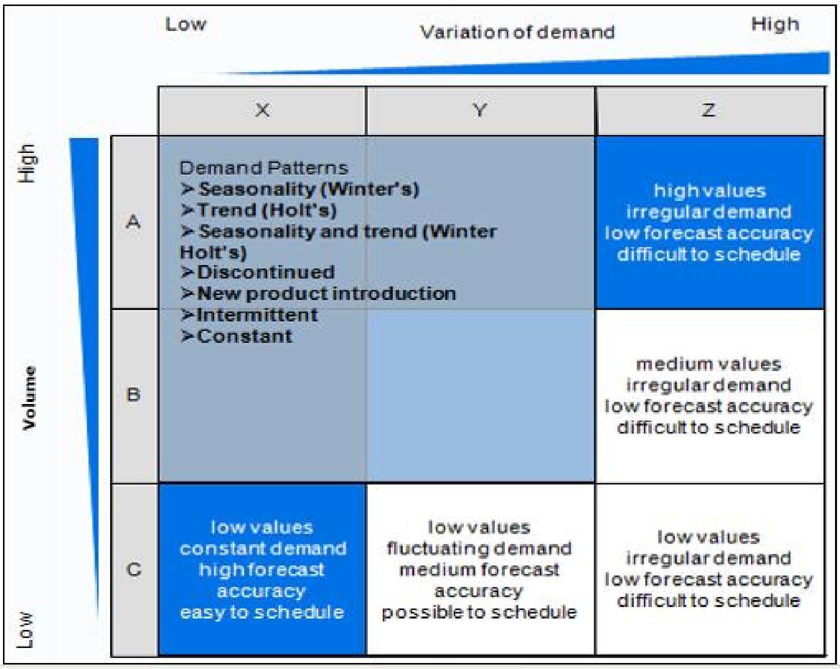


Figure 7 - ABC/XYZ classification

Products with low demand variability are the ones to which quantitative criteria can be applied. On the other hand, when the variability is high, human input is required more often.

From this analysis it is also possible to decide the production strategies. In general, product with low variability and high volumes are made-to-stock (MTS) products, while on the other hand the high variable and low volume one will be make-to-order (MTO).

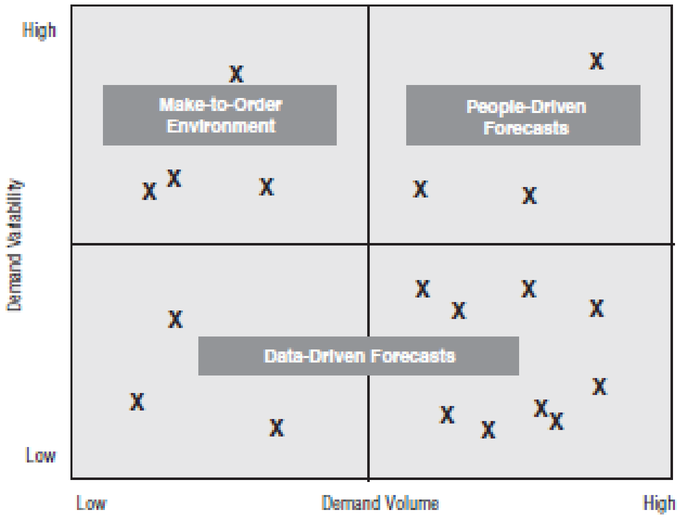


Figure 8 - Segmenting Product to determine appropriate forecasting approaches

To decide which forecast method to apply on the MTS items, a study on the nature of the demand is performed. The forecast methods can be qualitative or quantitative, and the latter is supported by several IT systems.

1.3.5.1.3 Plan Information Flow

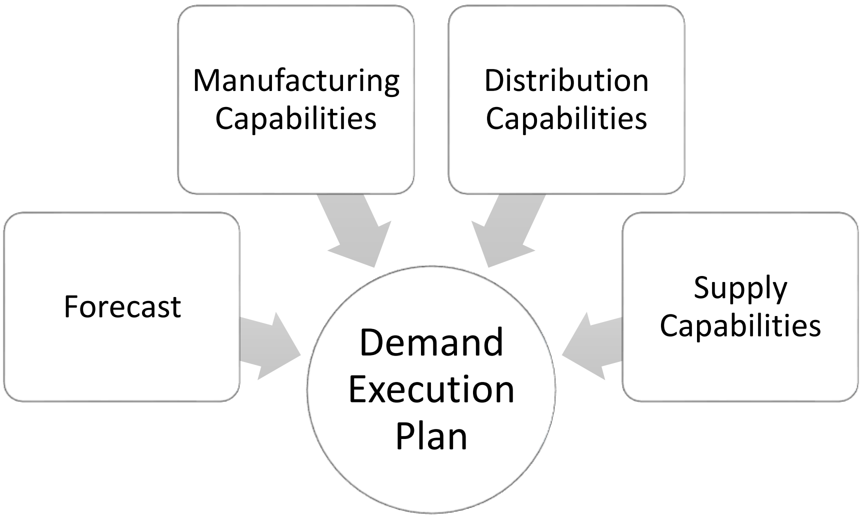
The sources of data need to be mapped in terms of what entity is going to supply it, how is it going to be developed, with what means is it going to be transferred, what interface is needed, how often will be provided and what is the relation with the provider.

Also, the destination of the demand information after the forecast is performed. This can be the case of the release of demand forecast to the supply planners or to other departments external to the company, for example other suppliers. Suppliers and customers can work together to forecast the end-customer demand, with visibility on when bottlenecks can occur and conjoint effort to avoid them.

1.3.5.1.4 Determine Synchronization Procedures

Key process for Demand Management is the synchronization between demand planning and supply planning. In other terms, the demand plan needs to be matched with supply, manufacturing and logistics capabilities. Nonetheless, the synchronization also needs to happen with other departments such as marketing, product costing, finance or sales force.

Synchronisation can happen in several ways, some more traditional such as meeting with a certain periodicity, or though IT systems.
Thanks to the ERP system, this flow can happen seamless between these departments and the requirements for the production can be determined though MRP runs and calculation on the timing for the components to be available at the premise to start the production and be able to deliver the product in time at the least possible cost.
Therefore, the output of the synchronisation will be a single execution plan that, taking into account costs, level of service, logistics and manufacturing constraints, will constitute the base for detailed manufacturing planning, capacity planning and detailed distribution planning.



Another level for the synchronisation that needs to be taken into consideration is the one with suppliers and customers. Including suppliers in the system, invite them to Sales and Operations meetings or stipulating with them stock keeping agreements, defining policies in case of fluctuation in demand to hedge the risk and spread it across members of the chain.

1.3.5.1.5 Develop Contingency Management System

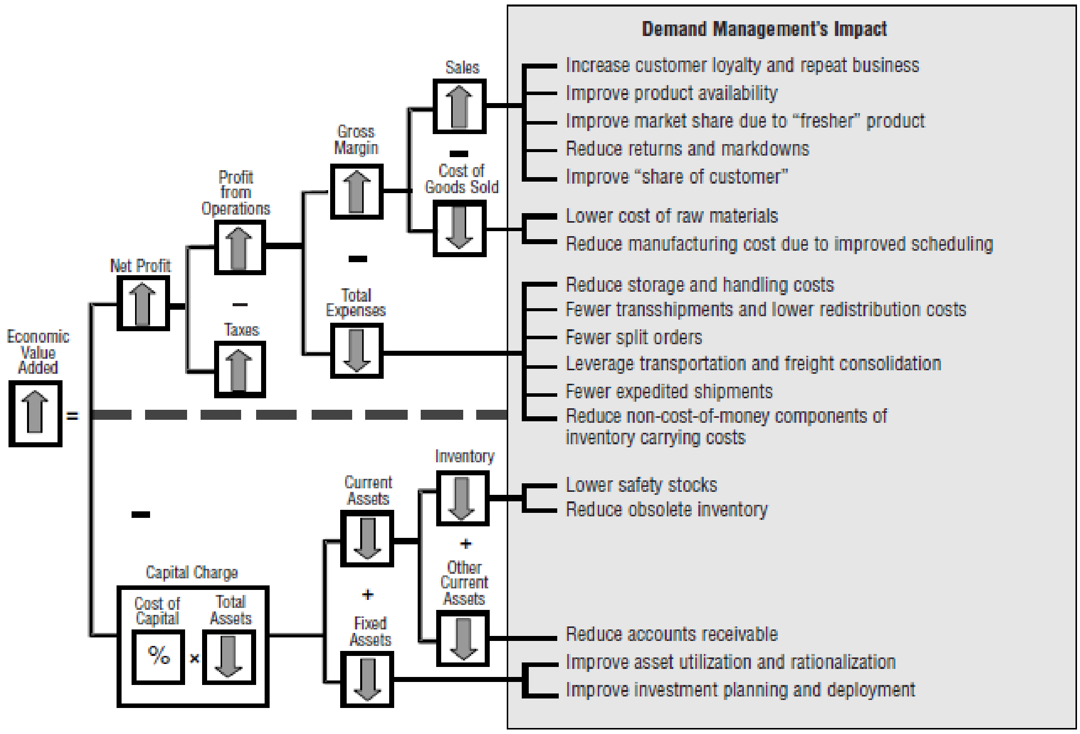
The development of contingency plans is necessary to cover the risk of a reduced service level to customer during downtimes, strikes or other unexpected events occur. Key part in this is the effective communication to the stakeholders, departments, managers and other parties involved.

1.3.5.1.6 Develop Framework of Metrics

Following Deming cycle, the last step in effecting management is monitoring and measuring the results. Uniform approaches to metrics within a company should be used. In order to develop metrics, it is necessary to understand how Demand Management can influence key performance metrics, and then include those in the analysis. With the final objective of adding value to the company, the impact of Demand Management can be discovered by exploding in a relation-tree the main drivers for the value added.

As a matter of fact, proper Demand Management can have a positive effect on gross margin, by increasing sales and decreasing the cost of goods sold (COGS). At the same time, it can also allow other costs saving on current assets such inventory costs and improve their utilisation.

In the picture below the diagram provides a visual explanation on the impact of Demand Management on EVA.



Source: Adapted from Douglas M. Lambert and Terrance L. Pohlen, "Supply Chain Metrics," *The International Journal of Logistics Management*, Vol. 12, No. 1 (2001), p. 10.

Figure 9 - Demand Management Impact on KPIs

1.3.6 Advanced Planning and Optimisation (APO)

1.3.6.1 ICT for Supply Chain: SAP APO

SAP has designed a system to support a range of processes in supply chain management.

The Supply Chain Management (SCM) application suite is comprised the following functionalities: Supply chain Planning, Supply chain Execution, Supply Chain Visibility and Supply Chain Collaboration.

Supply chain Planning	Supply chain Execution	Supply Chain Visibility	Supply Chain collaboration
• Supply Chain Design • Demand Planning • Supply Planning • Distribution Planning • Production Planning • Transportation Planning	• Material Management • Manufacturing • Order Promising and Delivery • Warehouse Management • Transportation Execution • Foreign Trade/Legal Services	• Supply Chain Event Management • Supply Chain Performance Management	• Supply chain Portal • Collaboration Processes • Supply Chain Integration

SAP Advanced Planning and Optimization (APO) is one of the most important modules in SAP Supply Chain Management (SCM) and it encompasses the all the functionalities mentioned above.

It is a powerful tool for decision making in relation to production and procurement, manage inventory, orders and demand in a dynamic environment.

SAP APO is able to apply complex algorithms and optimization techniques while incorporating resources and constraints to its calculations.

Supply Chain Planning steps can be executed by components in SAP ECC and others by SAP APO, and the two systems are integrated with each other.

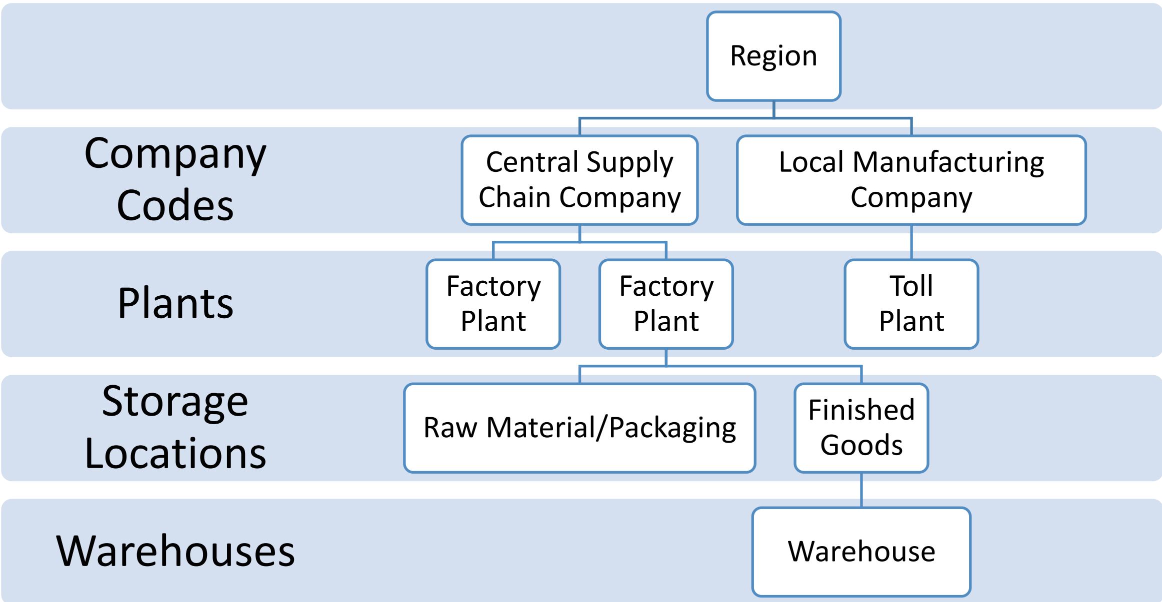
1.3.6.2 *Types of Data In SAP*

There are three levels of data in SAP ECC:

- ORGANIZATIONAL DATA: The enterprise structure is mapped in SAP using Organisational Data elements as for example Company Codes, Plants, Profit Centres, Cost Centres etc.
- MASTER DATA: Reference data that can be used and reused in transaction processing. They are organised into views and assigned to Organisational Data elements, for example Vendors, Materials, Recipes.
- TRANSACTIONAL DATA: the result of executing day-to-day business processes in SAP by combining organisational and Master Data, for example. Purchase Orders, Process Orders, Invoices.

1.3.6.3 *Organisational Data*

Below an overview on the Organisational Data structure in SAP:



An explanation for each element is provided below:

Org .Element	Purpose/Description
Company code	Legal entity that represents an independent accounting unit where balance sheets and P&L statements, required by law, are created
Plant	Logistics-based organisational element that is used by SD, MM and PP. It produces goods, renders services, or makes goods available for distribution
Storage Location	Physical place where stock is kept within a plant
Warehouse	When Logistics execution is in use, warehouse is physical place where stock is kept in on storage bins. Storage location becomes a virtual place necessary for GR (goods receipt)/GI (goods issue)

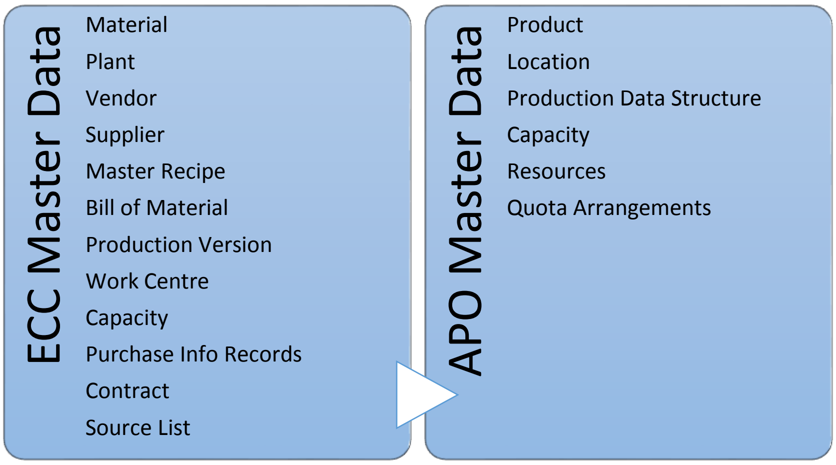
1.3.6.4 Master Data

In business, Master Data is information that has a key role in core operations and does not change very frequently. As a matter of fact, most Master Data objects have details that are relatively stable, and they are meant to speed up transaction processing greatly, as together with organisational data (e.g. plant) values will default into the transaction from the reference Master Data files.

Master Data is maintained in both the Master Data Management (MDM) system, in ECC directly, and in APO. Master Data is transferred across the systems.

The leading system for Master Data is always ECC and it transfers the data to APO using a function called Core Interface Function (CIF). The SAP APO Master Data objects are usually different from those in SAP ECC. During Master Data transfer, the relevant SAP ECC Master Data in mapped to the corresponding planning Master Data in SAP APO.

This is the overview of Master Data syndicated between the two systems:



1.3.6.5 Master Data Objects In Apo

The main Master Data in SAP APO system are related to:

- Product
- Production Data Structure
- Plant Location
- Distribution Centres
- Suppliers
- Customers

1.3.6.5.1 Product

The naming convention can be confusing as the Product Master in APO is related to Material Master in ECC. Nevertheless, the reason for changing the name is because the actual structure of APO Product Master is different from the ECC Material Master. Even though the data is the same, the APO Product Masters only show relevant information to supply chain planning. Below an overview on how the Master Data structure differs between the two systems:

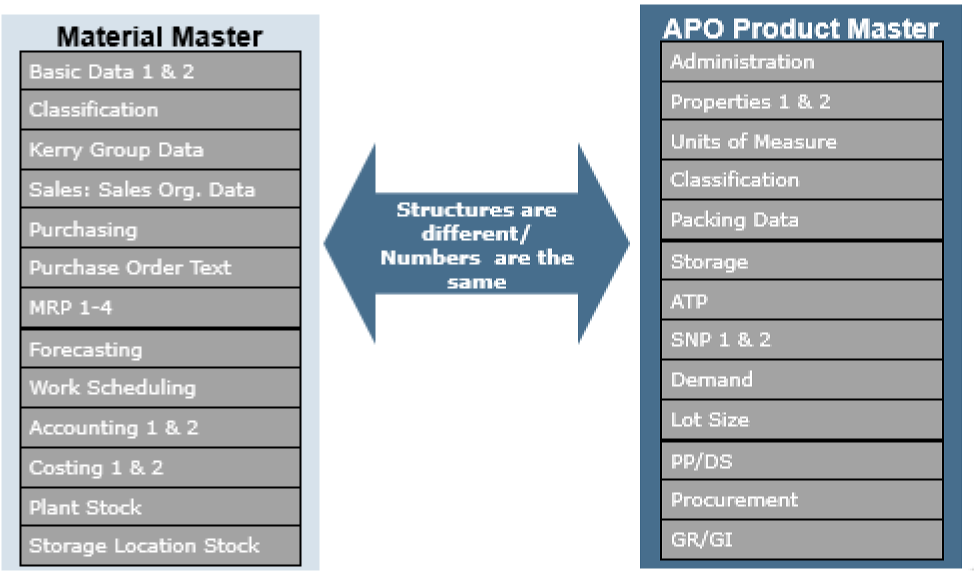


Figure 10 - Comparison between ECC and APO Master Data

It can be the case that some Master Data are stored in APO system only, especially in the case of the information relevant to planning in APO only. In this case, which is very limited, the master system is APO that transfers data to ECC via Core Interface.

Material Classification in SAP

There are many types of materials in SAP, and they can be classified as:

- Raw Materials (ROH): Purchased and used directly in recipes and/or bills of material.
- Packaging (VERP): Purchased and used directly in recipes and/or bills of material.
- Indirect material (ERSA): Purchased materials that are stocked but not used directly in recipes (e.g. spares).
- Intermediate Materials (HALB): Assembled as part of a manufacturing process and immediately consumed in the manufacturing process.
- Traded Goods (HAWA): Materials purchased for re-sale.
- Finished Products (FERT): Goods manufactured and sold.

  A product is anything that meets one of the following definitions:

  - Recipe plus packaging placed in stock and identifiable by an individual finished good code
  - A manufactured product
  - A traded good, for example a raw material bought for resale

- Any intermediate manufactured item

Products might:

- Be manufactured internally
- Be bought and resold
- Be co-manufactured
- Include raw materials bought for resale

1.3.6.5.2 Production Data Structure (PDS)

As per SAP definition, a PDS is structure generated from a production version or a bill of material in SAP ERP that contains information about the production cycle and the component assignment to produce a product;

Production data structures contain data from Bill of material, Routing and Master Recipe.

The production data structure can be used in SAP APO as a source of supply for in-house production.

1.3.6.5.3 Location

Location Master is provided with the following features:

- Locations are planned equally
- Demand can be fulfilled at any location
- Products can be stored at any location
- Storage, handling, supply and production capacities can be assigned to any location
- Storage costs and purchase costs can be defined for each product in each location
- Production, shipping and warehouse calendar can be defined for each product in each location
- Handling resources or storage resources can be assigned to location to display aggregated handling or storage capacities.

1.3.6.5.4 Plant and Distribution Centres

A Plant is an Organizational Unit that divides a company into production, procurement, stockholding or material planning. In a Plant, materials can be produced, or goods and services can be staged. Amongst other things, the plant defines an address, a language, a country assignment and a factory calendar.

Distribution centres are plants where the predominant activity is selling, or plants that are involved in the distribution of materials in general.

One or more storage locations can be defined within a plant. A storage location specifies where a material is stored, enabling a differentiation of material stock within a plant.

For plants in which production takes place, it is necessary to create:

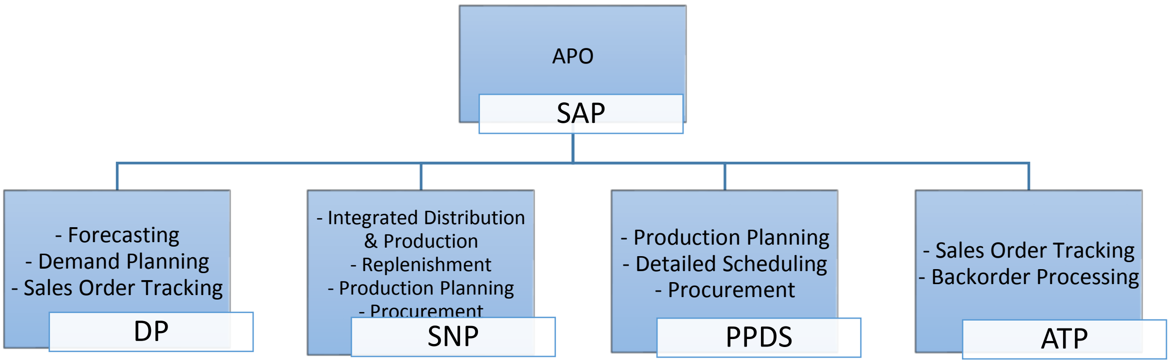
- Resources
- BOMs
- Routings
- Materials
- Transportation lanes, used to connect a network of Plants and DCs so that the stock transfer can be planned between these locations. Corresponding lanes can also be specified in SAP ECC in the form of Special Procurement Keys, for example.

The supply relationship between a supplier and a plant is defined in SAP ECC in the form of a purchasing info record or outline agreement.

1.3.6.6 Modules in SAP APO

SAP APO contains modules that can be used in isolation or in combination with one another. The time horizon and the level of detail are the main differentiators for each one of these processes. For this reason, SAP APO has been divided in modules, which are:

- Demand Planning (DP)
- Supply Network Planning (SNP)
- Production Planning & Detailed Scheduling (PP/DS)
- Available to Promise (ATP)



1.3.6.7 *The Horizons in SAP APO*

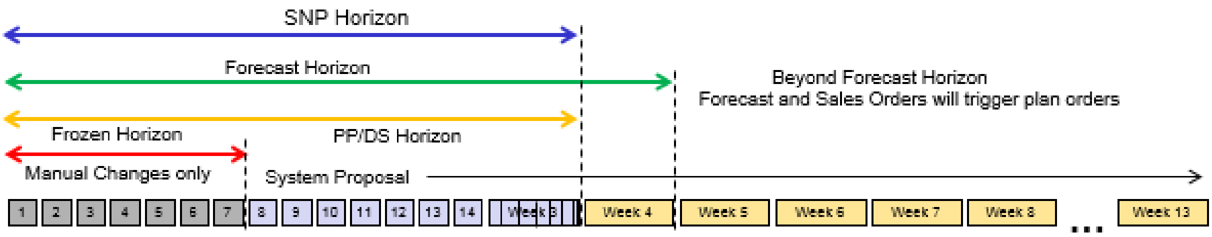


Figure 11- Explanation of SAP APO Horizons

SNP Horizon is the period that doesn't have automatic changes by SNP

- The Supply Planner is responsible for the plan outside this horizon
- The Production Scheduler is responsible for the plan inside this horizon

Forecast Horizon is the period where only Sales Orders and not the forecast will trigger demand to production. This functionality can be used to prevent Forecast driven planned orders to be created inside the Detailed Scheduling Horizon.

PP/DS Horizon is the period where system will propose an "optimised" production schedule according to requirements, capacity and production groups.

Frozen Horizon is the period where production scheduler will make changes manually.

New production required inside the Frozen Horizon will be scheduled immediately outside with an Alert Message to manually reschedule. For example, 3 days to 3 weeks.

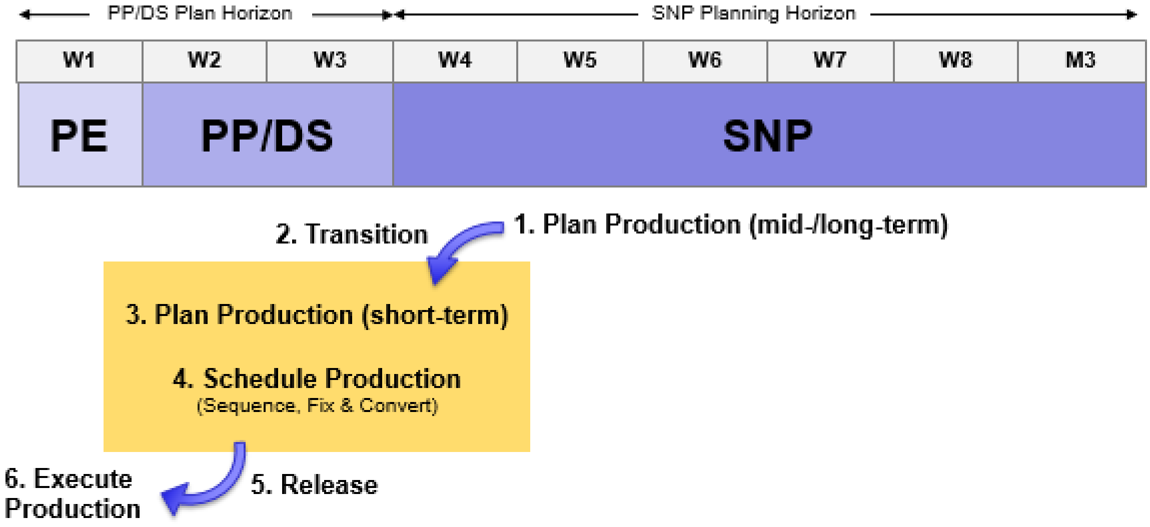


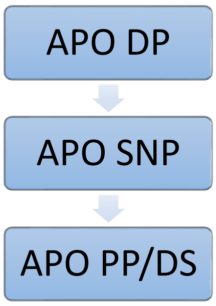
Figure 12 - PP/DS and SNP Planning Horizons

1.4 How SAP APO supports the Operational Demand Management Process

The operational Demand Management processes involve the actual performing of data collection, its forecast, the synchronisation with the other departments and its performance measurement. Variability reduction processes also needs to be involved.

1.4.1 Data collection and Forecast

1.4.1.1 Demand Planning (DP)



Demand Planning is a complex, powerful and flexible tool that supports the Company's demand planning process. Statistical forecasting and advanced macro techniques are used to create forecast based on sales history as well as any number of casual factors.

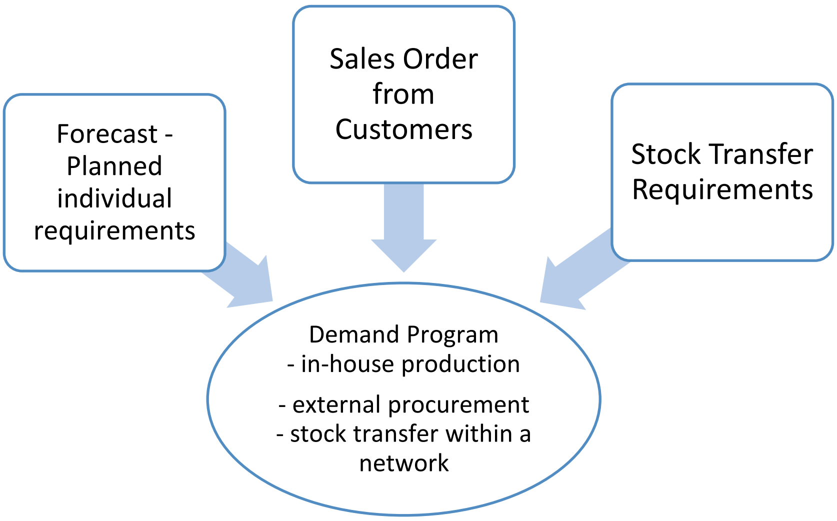
The purpose of demand planning is to anticipate customer needs by creating a forecast of independent material requirements. This is made to respond faster to fluctuation in demand and prevent stock-outs.

This can be done at a distribution centre level or directly in production plants.

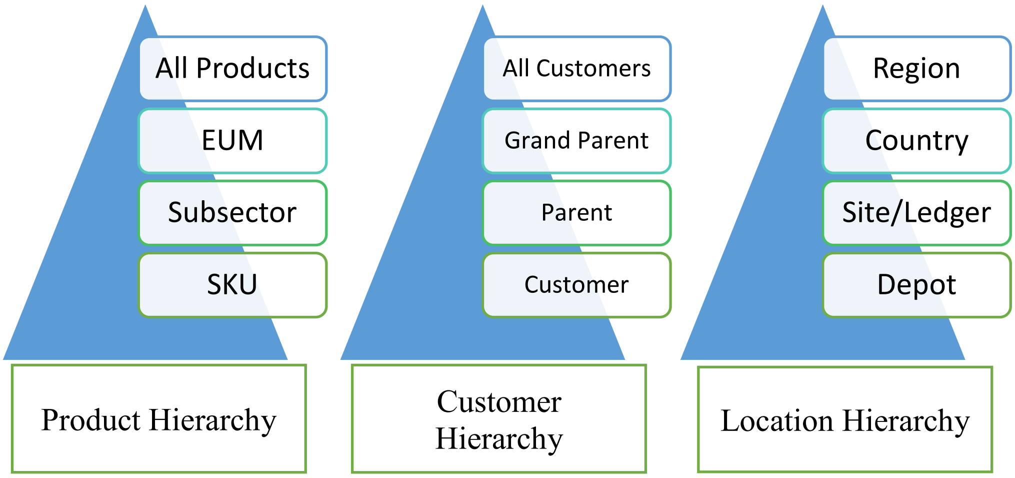
Demand planning provides an unconstrained forecast of future market demand and it is usually period-based. The period considered for the forecast is standard and it goes from the next 13 weeks to 18 months.

The final outcome of the forecast is Planned independent requirements for Supply Network Planning (SNP) and Production Planning and Detailed Scheduling (PP/DS).

As it is possible to see from the chart below, the planned independent requirements are part of the total demand that will be required at the plant.



The level at which a forecast can be performed can vary depending on the selection of the combination that gives the minimum error for the forecast. Below an overview on the level of aggregation/disaggregation:



The forecasts from Demand Planning to Supply Planning are released monthly every 3rd Saturday of fiscal month.

The production horizon is used to decide which requirements are to be planned in SNP and which are to be planned in PP/DS. Requirements that are not covered by PP/DS within the production horizon are covered by SNP outside the production horizon. In the following chapters the SNP and PP/DS modules will be analysed.

Overall, demand planning is the driver of:

- Budgeting plan
- Supply plan
- Purchasing plan
- Capacity plan

1.4.1.1.1 MTO and MTS and demand consumption

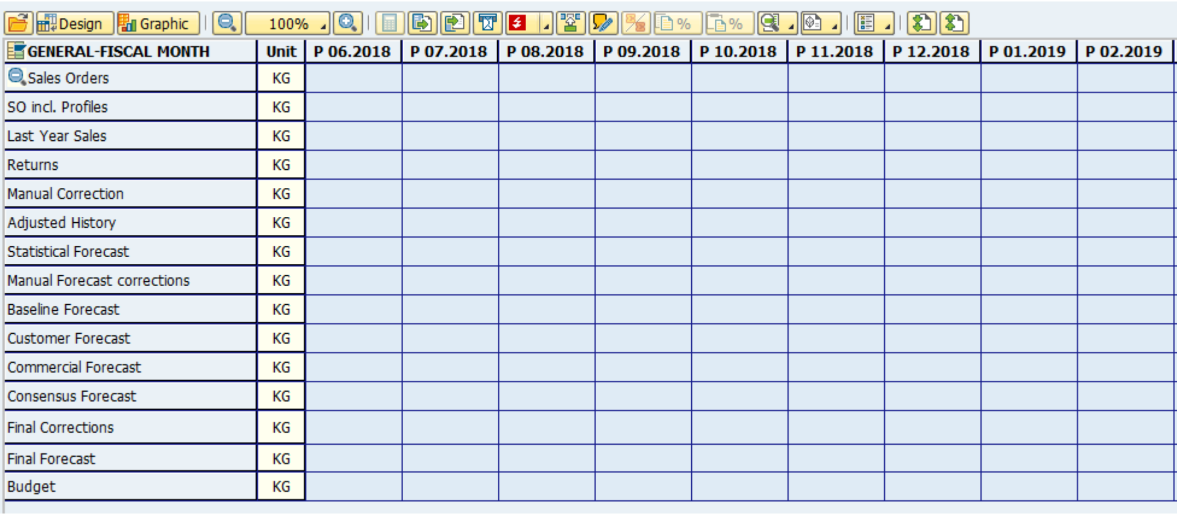
By using requirements strategies in SAP SCM, it is possible to determine which requirements are to be included in the planning process.

In pure make-to-stock (MTS) production, the procurement of material has to be initiated without having to wait for concrete sales orders to come into the system. In this scenario, only planned independent requirements are taken into account during planning. Using such a procedure, the delivery times can be shortened and forecast planning used to load the production resources as evenly as possible.

In pure make-to-order (MTO) production, sales order can serve as exclusive requirements sources, for which procurement is then specifically triggered.

Mixed strategies are possible whereby sales order can be used together with planned independent requirements to create the total demand. Demand consumption is also possible with planned independent requirements. Demand consumption is a process based on a background job that deletes the forecasted demand when an actual sales order is placed by a customer.

1.4.1.1.2 Demand Planning Book: the structure



GENERAL-FISCAL MONTH	Unit	P 06.2018	P 07.2018	P 08.2018	P 09.2018	P 10.2018	P 11.2018	P 12.2018	P 01.2019	P 02.2019
Sales Orders	KG									
SO incl. Profiles	KG									
Last Year Sales	KG									
Returns	KG									
Manual Correction	KG									
Adjusted History	KG									
Statistical Forecast	KG									
Manual Forecast corrections	KG									
Baseline Forecast	KG									
Customer Forecast	KG									
Commercial Forecast	KG									
Consensus Forecast	KG									
Final Corrections	KG									
Final Forecast	KG									
Budget	KG									

Figure 13 - The Demand Planning book on SAP

Explanation of the Key Figures:

- **Sales Orders**: Booked Sales History for Products, it is extracted at SKU/Customer/Depot Level
- **Last Year Sales**: View last year sales for a particular period in corresponding current period
- **Returns**: To view sales orders returned by the customers
- **Manual Correction:** To remove the effect of any unplanned or planned event that has caused a spike or dip in sales volume (make manual entry to adjust 'Sales Order' quantity)
- **Adjusted History:** is equal to Sales Orders + Manual Correction
- **Statistical Forecast:** Stat forecast calculated by the system
- **Manual Forecast corrections:** Any corrections to the statistical forecast figures can be done with an entry here

- **Baseline Forecast:** is equal to Statistical Forecast + Manual Forecast corrections. At every go live, minimum of 1 year of sales history is loaded. From the go live on, the data will continue to be kept and the historical data will grow. a statistical forecast model will be generated for all material/plant combinations.
- **Customer Forecast:** Forecast quantities committed by the customers.
- **Commercial Forecast:** Commercial team enriches statistical forecast with commercial and market intelligence. High value and high volatility products are discussed with Commercial through monthly meetings. Uploaded from excel or manual changes.
- **Consensus Forecast:** It is by default the commercial forecast and drives the budgeting and supply planning. If there are no commercial forecast, statistical forecast will be used.
- **Final Corrections:** Before the forecast is release to SP, any last-minute corrections that planner wants to do to Consensus Forecast.
- **Final Forecast:** is equal to Consensus Forecast + Final Corrections.
- **Budget:** is equal to Final Forecast (calculated at the start of financial year when budgeting is done). Accenture will load if the figure is supplied back from Finance. Used for comparison reporting.

The Demand Planning module offers the possibility to create forecast from the demand history based on a number of different casual factors, use a consensus-based approach to consolidate the demand plans of different departments, and use forecast corrections and promotions to take account of marketing intelligence and management adjustments.

1.4.1.1.3 The Univariate forecast

A univariate forecast predicts future demand based on a single variable, in general the historical data in relation to sales.

Elements that need to be considered when forecasting are the forecast model used to best fit the demand data, the ex-post forecast and the initialisation of parameters.

The Model

- Constant
- Trend

- Seasonal
- Seasonal with trend
- Moving average
- Auto selection
- Croston model for intermittent demand
- Historical data model
- Manual forecast
- Linear regression
- No forecast

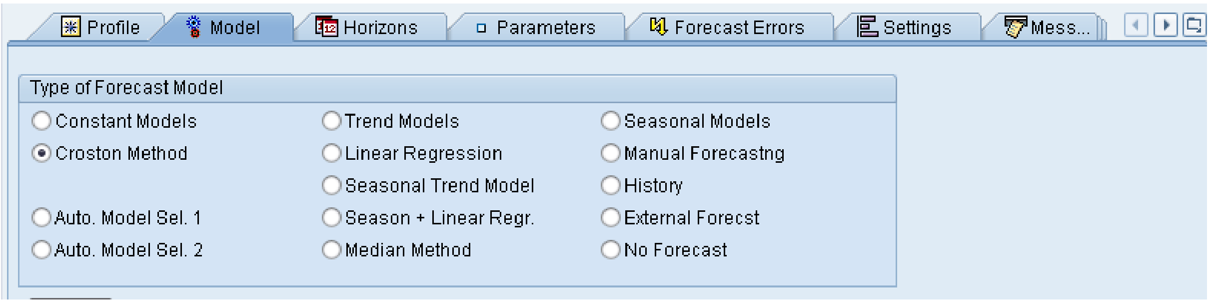


Figure 14 - Forecast Models available in SAP APO

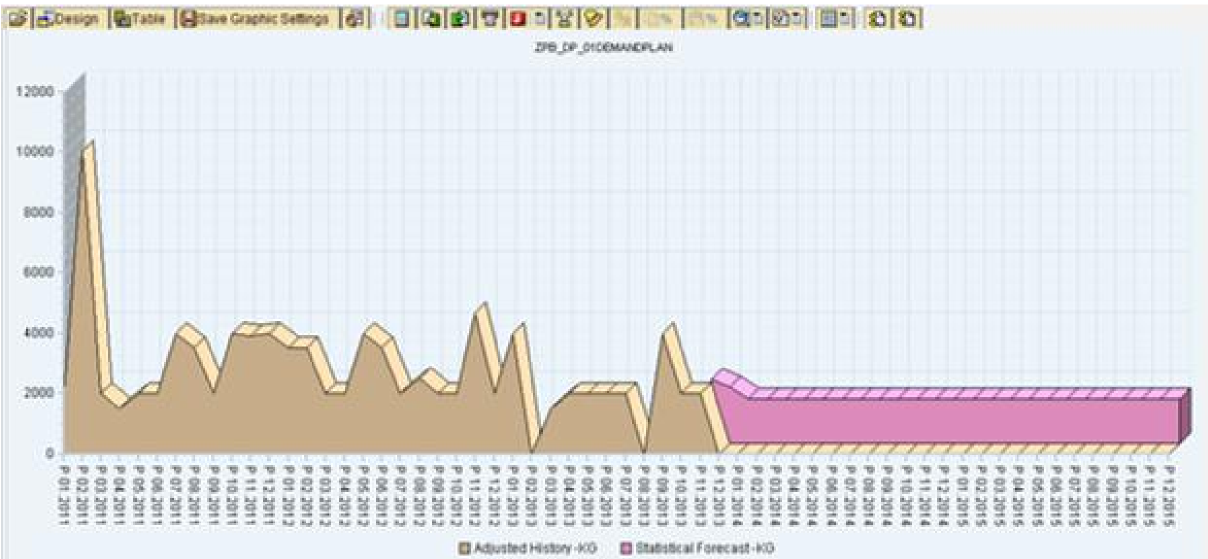


Figure 15 - Example of forecast graphic in SAP APO

The Ex-Post Forecast: An Ex-post forecast is a forecast that runs when there is historical data available. It divides the time in two, past and present and compare the ex-post forecast against historical values to calculate the forecast accuracy. The ex-post forecast is used to measure model fit. The past data is further used to initialise the model.

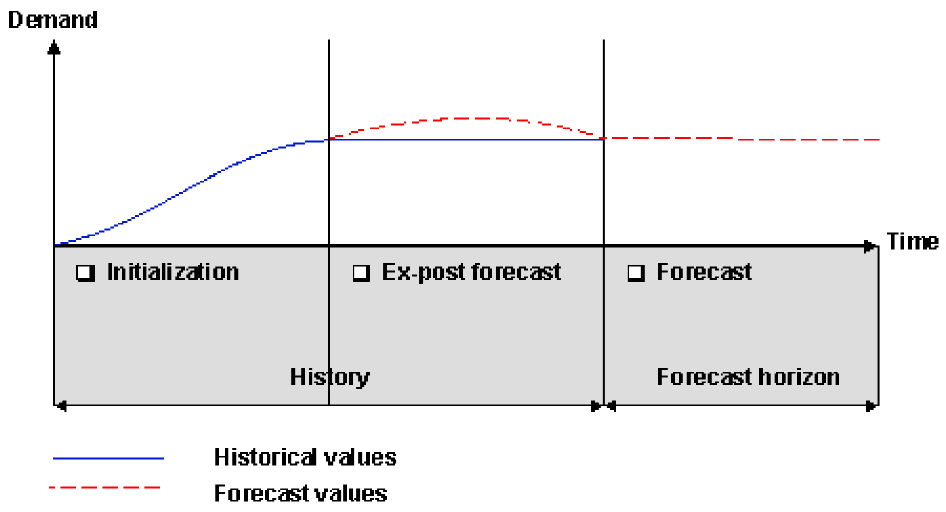


Figure 16 - Forecast process segmentation

The Initialization:

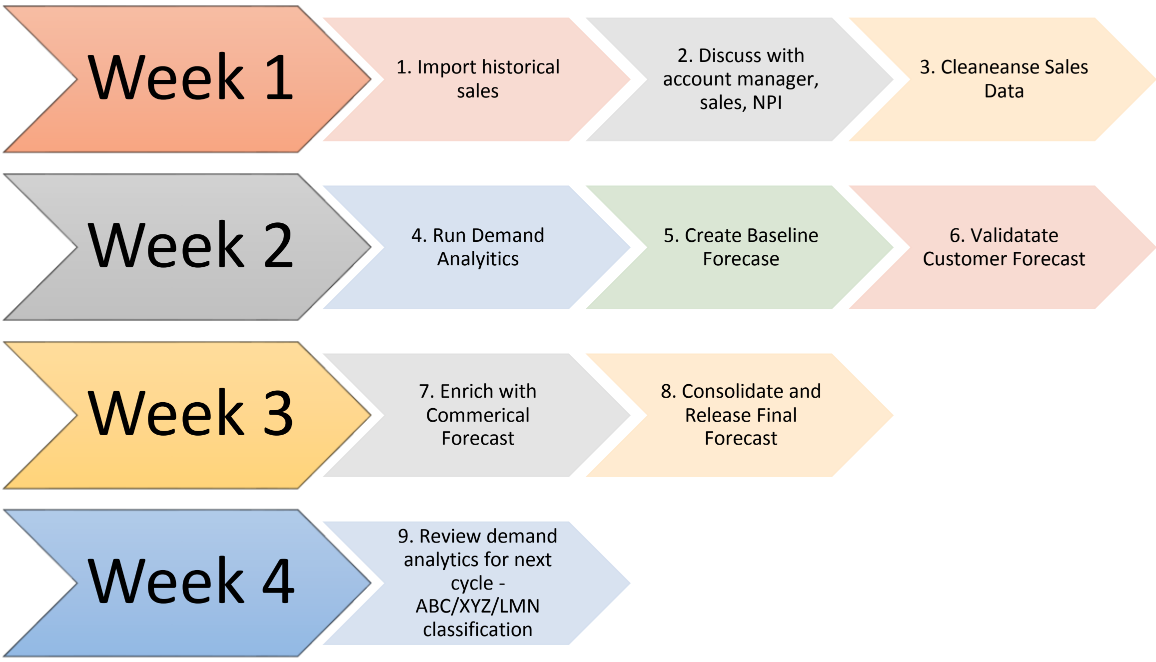
Forecast Model	Fixed number of historical values used for initialization
Constant	1
Trend	3
Seasonal	1 season
Seasonal and trend	3 + 1 season
2nd order exponential smoothing	3

The model parameters, Alpha, Beta, and Gamma, control the weighting of each historical value:

- Alpha is used in the Basic value calculation.
- Basic value and it determines the how much, more recent, or how many periods in the past should be weighted in the forecast calculations. A higher value means more recent data points are given more weight.
- Beta is used in Trend value. It determines the degree of ascent or descent value that should be used to adjust the forecast. This tells the system how much to focus on recent changes in trend.

- Gamma is used in the Seasonal index calculation. The higher the parameter, the more recent the recent seasonal component is weighted.

The value for the parameters range from 0 to 1. A higher value will place more emphasis on recent history. The parameters also control how reactive the forecast is to changes in historical patterns. As a final step, the presence of outliers needs to be assessed.
A summary of the monthly Demand Planner workflow is shown below:



1.4.2 Synchronisation

Synchronisation of demand planning with supply planning happens at the demand forecast release. Because the forecast is unconstrained, the supply planning will generate a demand execution plan keeping in mind the presence of constraints such as budget, resources or capacity. It integrates with purchasing, production, distribution and transportation creating a long-term tactical feasible plan.
The planning board for supply network planners is where all this information is stored and can be used as communication tool for the stakeholders.

1.4.2.1 Supply Network Planning (SNP)

Supply Network Planning is a period-based, medium-term, cross-plant planning process that plans production outside the SNP production horizon and plans procurement outside the stock transfer horizon. The period that cover goes from the 4th week in the future up to 2 years.

It is a rough plan with granularity only until days, not minutes and seconds. Within this plan are considered resources such as men power, machinery and materials.

The rough-cut capacity plan (RCCP) is used to proactively manage the issues that can arise when manufacturing a product, such as bottlenecks, shortage of materials etc.

The outcomes of the Supply Network Planning activities along with the RCCP are also a Distribution Requirement Planning (DRP) and Master Production Schedule (MPS). It also generates SNP Planned Orders or SNP Purchase Requisitions, depending on the type of procurement whether is in-house production or external procurement.

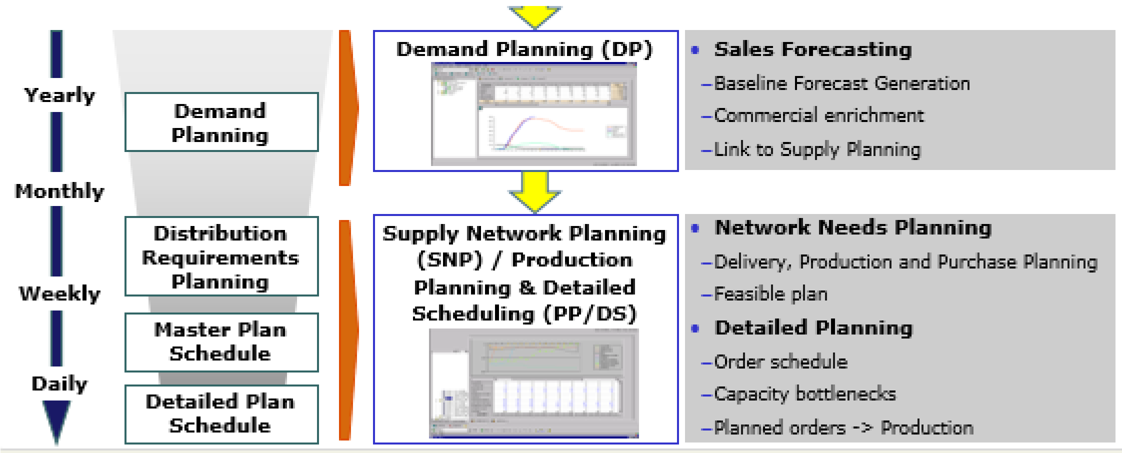


Figure 17 - Overview on Demand Plan release to SNP and PPDS

SNP planning is based on SNP bills of material and routings and usually involves simplified Master Data. SNP BOM, for example, usually contain only the strategically important components for which forecast planning is necessary, whereas procurement of the remaining components is only planned in plant-specific detailed scheduling.

1.4.2.2 Production Planning and Detailed Scheduling (PPDS)

Production planning is used for short-term planning with exact times in the production plant, for both in-house and external procurement. Production planning covers requirements by generating PPDS planned orders to plan in-house production as well as purchase requisitions for external procurement.

It is based on Master Data records, specifically plants, material maters, bills of material (BOM), and routings (PP) or master recipes (PP-PI).

Production Planning and Detailed Scheduling timeframe goes up to 3 weeks in the future. In this case, the granularity is until seconds as it is used for short-term, order-based planning according to sequences and setup times.

2 TECHNICAL BUILDING BLOCKS OF SAP APO

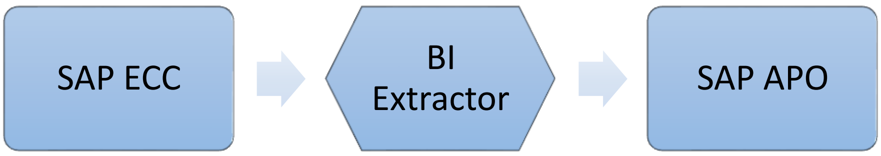
2.1 THE ARCHITECTURE

In regard to the technical application, APO is made of three parts:

- The Business Warehouse (BW) database
- The Business Intelligence (BI) data mart
- The Live Cache, a huge memory used to increase performance for complex calculation and where the planning and scheduling relevant data is kept.

Business Information Warehouse (BW) is a software distributed by SAP that aims to group together and format the huge amount of business data. SAP Business Information Warehouse makes available information in a quick and optimised fashion in order to allow SAP BI (Business Intelligence) to provide quick and better-quality data to decision maker in the business through BI Reports.

Data gets extracted from ECC by a BI Extractor[2] and then loaded into APO. At the moment, for the materials shared and available in SAP APO, this process is carried out at a Finished Good (FERT) level.



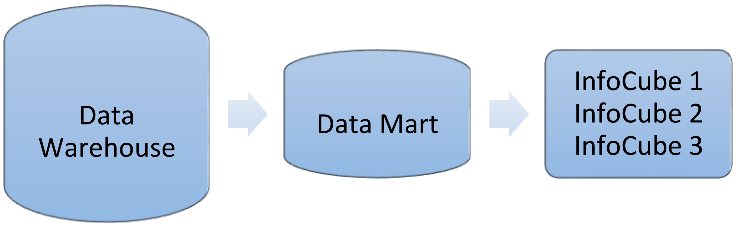
2.1.1 Data Warehouse and Datamart

As Standen (2008) suggests, a Data Warehouse is a storing system that holds very detailed information in relation to multiple subject area. It does not necessary make use of dimensional models, but it is rather used to feed information to dimensional models, such as an InfoCube. The concept of dimensional models and InfoCube will be explained in detail later.

Data Mart, on the other hand, holds data in relation to one subject area, for example Finance or Supply Chain, and it is less detailed than in the previous case. This is designed in order to

[2] BI Extractor=

make the access to the data faster to the user. Nevertheless, it can be set up with a good level of detail if needed. A Data Mart is made of InfoCubes.



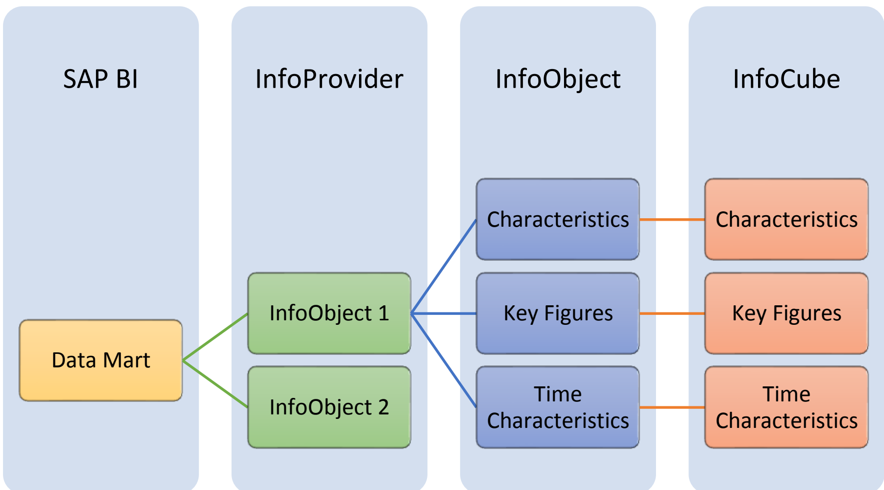
2.2 InfoObjects

InfoObjects are the smallest unit in SAP BI and are used in InfoProviders, entities that group a number of InfoObjects together. They are used to map information in a structured form and they can be used in reports to analyse the data stored and to provide information to decision makers.

InfoObjects can be categorized into:

- Characteristics, like Customer, Product, Company Code, Period
- Key Figures, in general they are quantities like Total Revenue, Profit, with the respective unit of measure
- Time Characteristics, like year, quarter of year

In order to keep the planning consistent, data is stored at the most detailed level and then aggregated and disaggregated as per Business decision.



2.3 Dimensional Model

A Dimensional model is a database structure that allows to enhance the performance of the system in terms of responsiveness and fastness. A Dimensional model is composed by Fact tables and Dimension tables. These tables are designed so that large Fact tables are surrounded by multiple smaller Dimension tables.

2.3.1 Dimensions

2.3.1.1 Characteristics

Characteristics are Attributes used to describe entities such as Vendor, Product, Customer. Characteristics that logically belong together are stored in the Dimensions.
For example, a Dimension table for the Customer can hold Characteristics such as the Customer Key, the Address, the Full Name, the Country.
Characteristics can be converted in Navigational Attributes.

2.3.1.2 Navigational Attributes

Navigational attribute comes from Master Data attribute that can be used to easily navigate reports. Navigational Attributes are used when there are levels on which the data is only displayed and no planning or statistical forecast is performed, therefore when they are not part of the key for the data access.

2.3.2 Fact Tables

The Fact tables contain Key Figures and Characteristics that are usually expressed in numerical value to be counted or summed or to be used for other types of operations. Data Analytics is performed thanks to the information contained in these tables.
These characteristics and key figures are stored in database objects called InfoCubes.
Below, the orange colour shows a Sales Fact table with its Dimension tables composed by Product, Customer, Time and Order.

2.4 INFOCUBES

An InfoCube is a set of relational tables which are logically joined to implement the star schema. It is used to store data physically and can encompass one or more related Business processes, and its data can be extracted on reports. The historical data that it stores is persistent in time. Demand Planning uses Business Intelligence (BI) functionalities such as the InfoCubes as data interface with other systems such as ECC, BW or flat files.

Business Intelligence Warehouse allows to define up to 16 dimensions, despite 3 being pre-defined.

The Master Data lies outside the InfoCube and feeds information to the 16-dimension tables.

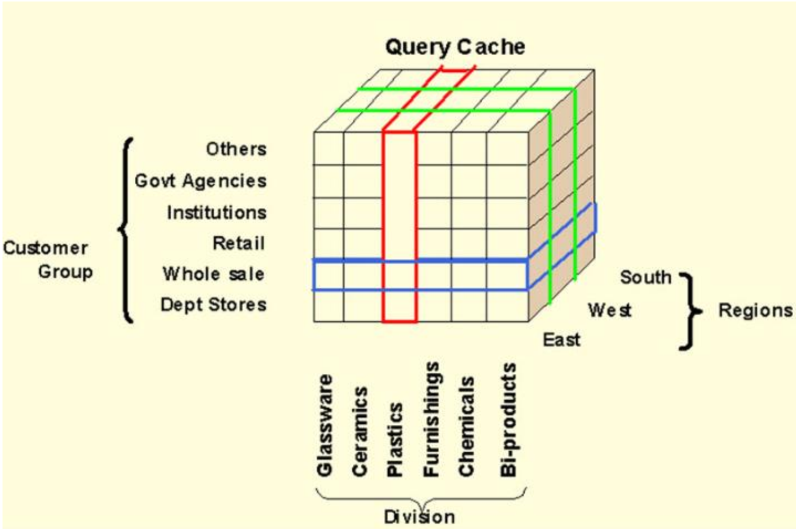


Figure 18 - InfoCube and its Dimensions. Source: www.guru99.com

The simple InfoCube in this example shows three Dimensions. Each dimension can contain up to 248 characteristics, and one square represents the relative value for the corresponding Customer/Region/Division combination.

The Key Figures depend on the Characteristics of its Dimension. Granularity of Key Figures in an InfoCubes stores aggregated data for a long period of time.

Data are added to a InfoCube from a InfoProvider or InfoSource.

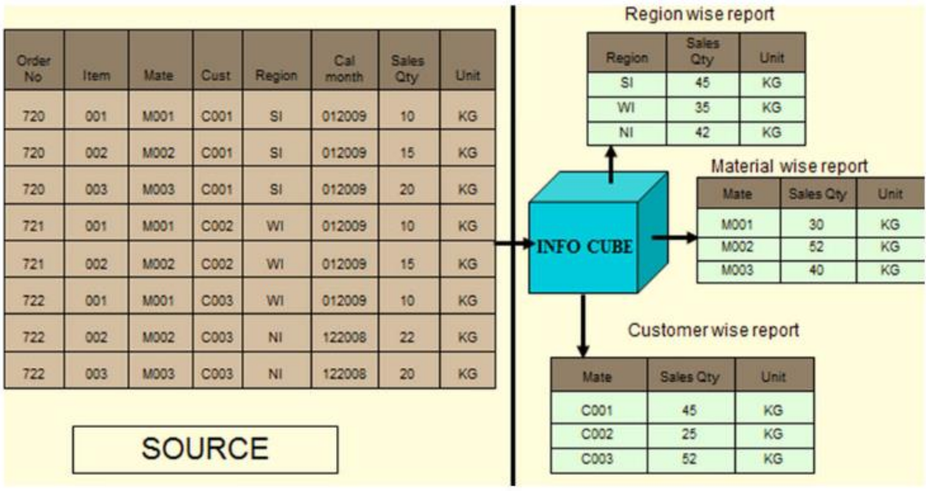


Figure 19 - Flow of data from the source to the InfoCube and its Dimensions. Source: www.guru99.com

2.5 CHARACTERISTICS VALUE COMBINATIONS

A Characteristic Value Combination is a key Planning Object that is used to access data and it is stored in an InfoCube. CVC is a combinations of value such as:

- APO Product
- Major Code
- Minor Code
- Ship-to Party
- Sold-to Party
- Customer SKU
- APO Location

A new CVC can be manually created but it can be configured to that it is automatically created everytime a new combination of the categories mentioned above appears in the InfoCube.
The CVCs are related to a Planning Object Structure (POS).

2.6 PLANNING OBJECT STRUCTURE

A Planning Object Structure contains characteristics relevant for Planning, and these Characteristics define the level and how the data will be stored. When a POS is activated, an InfoCube is created with the same name and the CVCs are stored in this InfoCube.
Planning Object Structures define the Characteristics that will be used for one or more Planning Areas.

2.7 PLANNING AREAS

A Planning Area is a central data structure that lists all the characteristics and contains a collection of key figures to be used in the planning process. Along with the Key Figures, also the Fiscal Year Variant, Storage Bucket Profiles are defined for a Planning Area.
Moreover, for each Kery Figure, a Time-Based Disaggregation type and Calculation can define the level at which aggregation and disaggregation is performed.

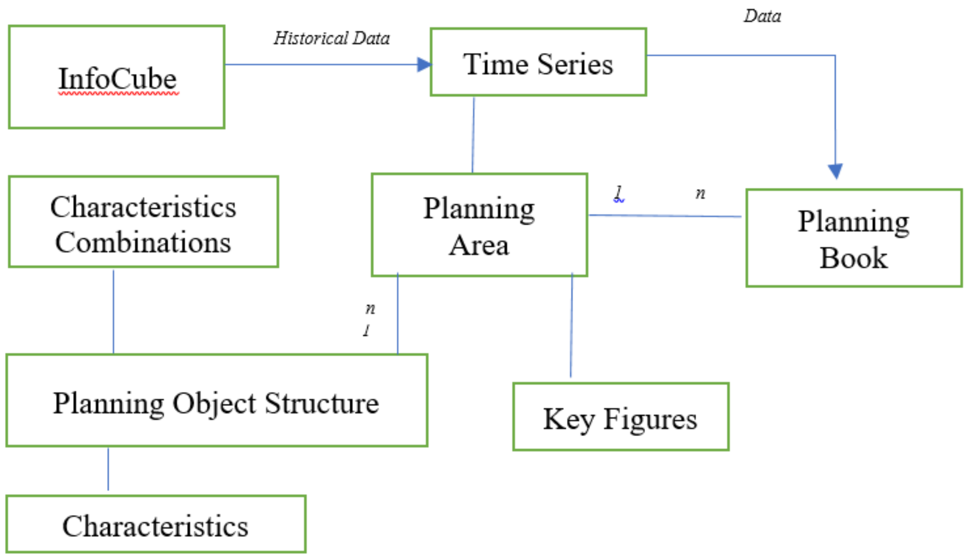
The Calculation type can be based on proportional factors or based on other types of calculations. The most common Calculation type is the proportional factor, but it can be overridden by Demand Planners based on experience.
The Time-Based Disaggregation type defines how planning data is disaggregated in time. The time-based disaggregation is of particular interest in business scenairos where the majoirty of sales happen during a certain peirodof the year.
For a detailed overview of Calculation and Time-Based Disaggregation types, please refer to the Appendix.

2.8 Planning Books

A Planning Book is used as a interface for the direct interaction with the users. It can be used for analysing the forecast results but also to perform other tasks such as removing the historical outliers. Planning Books have different time bucket views and Data Views based on informaiton requirements.

2.9 Data Views

Data Views allow the user to examine information from different angle and give a degree of flexibility for the analysis. Example of the most common Data Views are historical data, key figures and forecast-related Key Figures.
In conclusion, the following diagram can help the reader to understand better the concepts explained above:


InfoCube
Historical Data
Time Series
Data
Characteristics Combinations
Planning Area
1
n
Planning Book
n
1
Planning Object Structure
Key Figures
Characteristics

3 THE PROBLEM OF FORECAST ACCURACY FOR FLAVOURS

3.1 THE MARKET FOR FLAVOURS

The reason why the need for an accurate demand forecasting for flavours in India is so urgent lies on the fact that the predictions for this sector are massively positive.
Globally, the market for flavours is forecast to grown at a CAGR[3] of 3.6% from 2015 to 2020, according to a research published by Lucintel (2016).
Looking at the geography, while North America is expected to remain the largest market due to growth in end use applications, Asia Pacific is expected to witness significant growth over the forecast period because of increase in disposable income and changing lifestyle (Lucintel 2016).
For these reasons, the decision to improve the demand planning process has been given a priority in the greater picture of the Continuous Improvement projects.
An iterative approach following the Deming Cycle has been used for the analysis and implementation of the solution proposed by this project, and the detailed steps will be shown in the following part.

3.2 THE INITIAL GLOBAL TEMPLATE ROLLOUT

When the SAP Global Template[4] has been deployed in the Indian Production Sites, the forecast procedure was standardised to align it with the other Company's Sites. In this scenario, the forecast is performed at a Finish Product (FERT) level.

[3] CAGR is defined as annual growth rate of an investment over a specified period of time longer than one year. The calculation for the CAGR can be found in Appendix.
[4] The Template Rollout is a software deployment approach to implement a SAP solution into subsidiaries that links business processes which are standardized to a certain extent

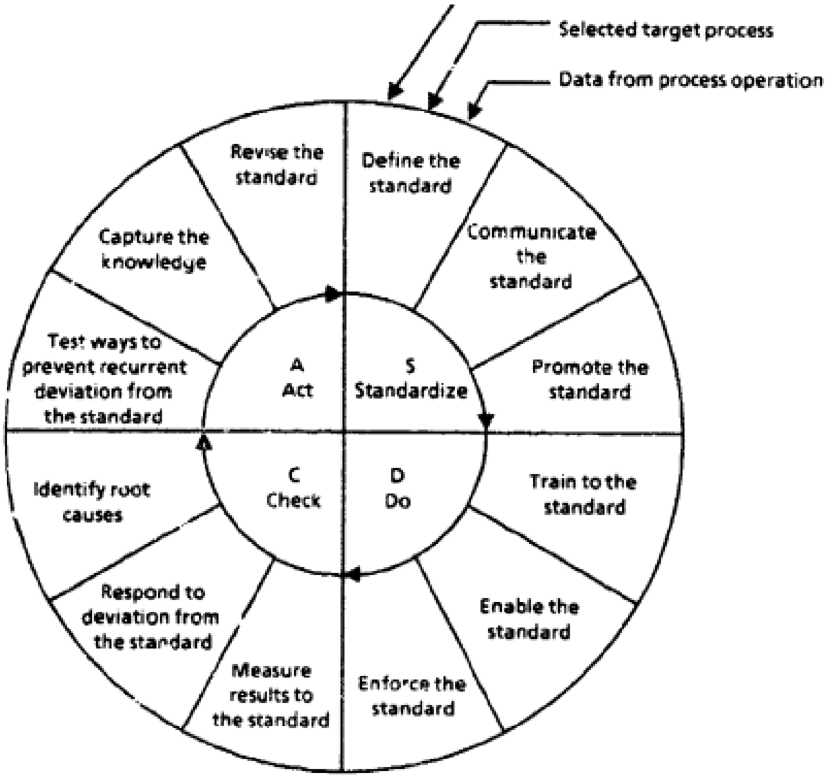


Figure 20 – Detailed Deming Cycle

During the "check" phase, it has been noticed that the Forecast Accuracy for certain type of products in the Indian Plants was very low, in particular for the SKUs belonging to flavour products.

The global targeted Forecast Accuracy has been set by the Company to be at 75%, but a high deviation from the expected result was noticed.

Within the Company, the Forecast Accuracy for flavours globally struggles to achieve the expected result but the problem encountered in India was far worse than, for example, the equivalent sites in EMEA[5] Region.

3.3 Root Cause Analysis – Fishbone: Why the problem in India is so big

The Fishbone diagram allows to understand what causes can be link to the same effect (problem), very useful during brainstorming activities.

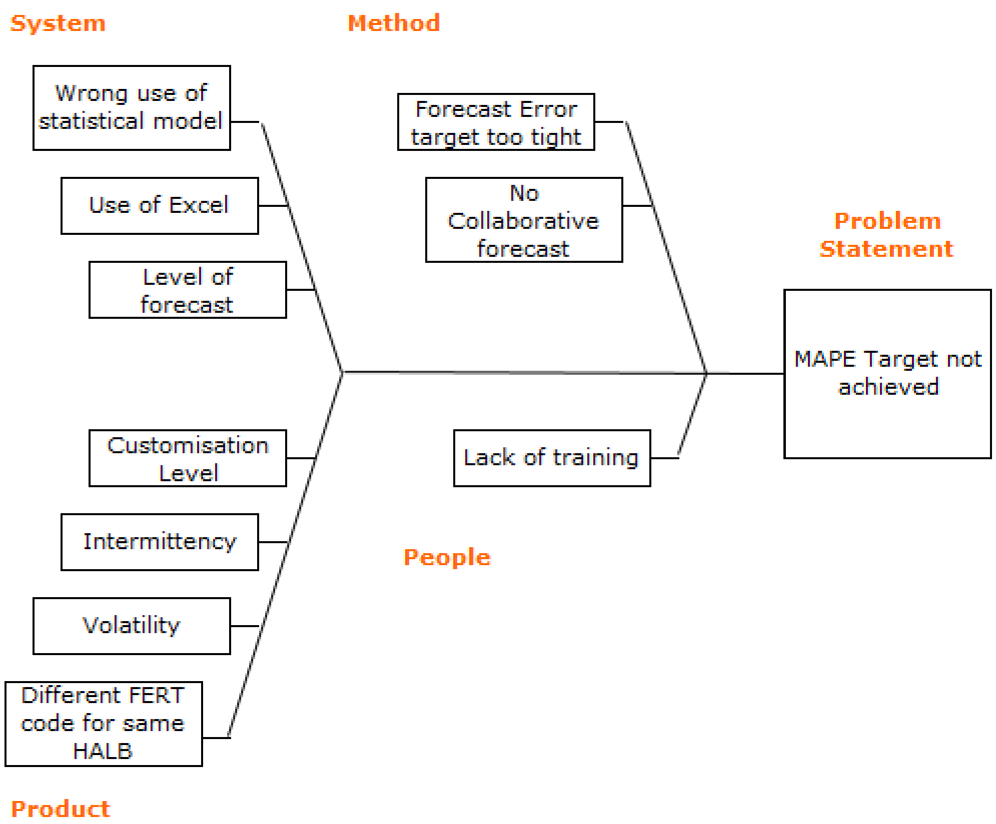
[5] EMEA is an acronym that stands for Europe, Middle East and Africa

Once the problem to be analysed has been agreed upon, it can be written down and the actual causes enumeration can start.

For the purpose of this project, the problem encountered is that the Indian Sites have failed to achieve the MAPE Targeted for flavour SKUs which is 25%.

In other words, the forecast released to supply planners was poor and has not able to drive good supply chain performance and provide useful insight and therefore potentially causing risk to the business such as stock-outs, excess of stock or poor service levels to the customers.

The causes have been divided into four categories: System, Method, People and Process.



3.3.1.1 Product

3.3.1.1.1 Different FERT codes for the same HALB

During the SAP Configuration phase, different FERT codes for the same HALB were set up.

In this way the same HALB can be contained in different FERTs and, despite being the same Finished Good they have different SKU codes. When the forecast is performed, it is done at a FERT level, and therefore there is no link between the SKUs that share the same HALB code.

3.3.1.1.2 Volatility and Intermittency

Volatility is defined as the tendency of sales orders to be spread out around the mean value, and it is generally measured by the Standard Deviation.

Volatility can be driven for example by a product's seasonality, new product introductions or promotions. Volatility is a phenomenon that is increasing in general across the industries because the customers are less and less loyal to a brand and the presence of strong forces into the same market make it difficult for a Company to achieve and maintain a competitive advantage.

On the other hand, intermittency measure defines how constantly an order is placed for the same item. Constant ordering pattern are easier to forecast than highly volatile and intermittent ones.

There are certain factors that can influence the ordering pattern such as Minimum Order Quantity (MOQ), Lot Sizes and Lead Times that can be controlled by the Company in order to create a more stable demand pattern. For example, the presence of Minimum Order Quantities or Minimum Lot Sizes can prompt the customer to buy a certain product sporadically, but on the other hand it can stabilise the volatility of the quantity demanded.

3.3.1.1.3 High Customisation Level

Several researches show that for the flavour Industry the ability to be highly customisable is an essential requisite. Research firms such as PMA also point out how customers are more and more dedicated to personalising their nutrition while seeking for taste and functional benefits. According to a research from Mintel, nearly 3 out of every 4 Young Millennials would like to experience more new flavours when dining at restaurants and build their diet programs and menus.

3.3.1.2 System

3.3.1.2.1 Product Level Forecast

The current solution for Forecasting is designed to perform the forecast at a FERT level, as the sales orders are keyed into the system and automatically flow into the Planning Book and the measure is coherent with the Finish Good level. This level is the easiest level to forecast product against the sales, but not always is the most appropriate. As a matter of fact, as discussed before, there are FERT codes in the system that share the same HALB and therefore the forecast should ideally be made against the latter one.

3.3.1.2.2 Use of Excel

As it has been ascertained in some Site visits, there are still a good percentage of demand planners that keeps using Excel Spreadsheet as a tool to forecast the demand for their products, mainly because of the sense of security with the Excel tool and the habit of working on it and sometimes because of the lack of confidence in the SAP Planning tool after having experienced poor forecast performance. Nevertheless, the use of Excel has a backlash effect on the accuracy of the forecast in the SAP system as less and less information is fed into the it and therefore the system has less data to make decision on. It has also several other pitfalls such as the lack of visibility from other departments, decision makers and stakeholders.
Also, when working with Excel, the additional challenge of consolidating different forecasts into a single comprehensive number is often difficult and can cause delays and inaccuracies.

3.3.1.2.3 Wrong use of statistical model

When a demand planner plan for the SKU, the system provides the user with the choice between different forecast models. Some of them are manually selected by the user based on its knowledge and it ability to predict how much the product will sell and some external effects that the system cannot forecast, some other are automatically selected by the system based on tests on demand patterns such as trend and seasonality. If the quality of data is not accurate, a bias will be introduced, and it will bring the system to generate a poor forecast when the automatic forecast model is selected. This can also be true in the case of external events that the system cannot predict. In this case, the automatic model selection can be risky as the shift in patterns will not be taken into account.

3.3.1.3 People

3.3.1.3.1 Lack of training

It is possible that demand planners have not been trained enough on the system so that they could perform forecast at their best knowledge. It could be the case of new learning sessions with users to be scheduled and new learning material to be handed over.

3.3.1.4 Method

3.3.1.4.1 Forecast Error Target too tight

It can be the case that a global target of 75% forecast accuracy could not be applicable to all SKUs across the business, and it could be necessary to revise the target to establish a most likely objective, that could be for example around 60-65% for products in the flavour industry.

3.3.1.4.2 No Collaborative forecast used

In order to take advantage of the expertise in relation to products shared across a supply chain, it is important to take into account the key role played by Collaborative Forecasting, which is currently a functionality not used for the flavour SKUs analysed for the purpose of the thesis. This can be probably due to the inability or the reluctance to share sales data, planning data or alert in relation to exceptional events.

3.4 SCOPE OF THE ENHANCEMENT IN RELATION TO FORECASTING AT HALB LEVEL

In order to create value to the Company by developing a solution to improve the performance in term of Forecast Accuracy and reduce the Mean Average Percentage Error for the flavour SKUs in Indian Production Plants, a new enhancement has been designed within the SAP APO system. The elements in scope are the creation of a new Planning Area, the creation of New Characteristic Value Combinations, a new Master Planning Object Structure, Planning Book and Data Views.

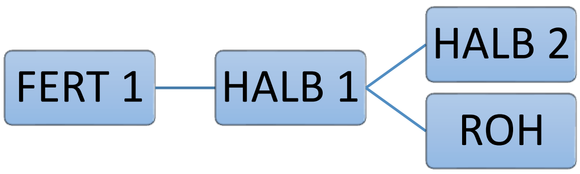
The creation of Selection IDs and a realignment template will be also required.

3.5 ELEMENTS NOT IN SCOPE

It is important to point out that the solution does not aim to be used for reporting purposes. Therefore, for the moment, no BI involvement is needed.

Another fact to highlight is that the solution will only forecast HALB at the first level on the BOM and not HALBs at every level. This is insured by the fact that the user will be the responsible to maintain the Selection ID for the relevant HALBs, and they will be only the first level.

This is important to avoid cases such as multilevel BOMs in which the FERT contains a HALB that is composed for example by another HALB but also a ROH. If the forecast was to be performed at the second level HALB, then the ROH material would have been left out from the forecast and, at FERT production, the ROH material would be missing.



3.6 CONCERNS ABOUT FORECASTING AT HALB LEVEL

3.6.1 Forecast disaggregation at release to SNP

Once the final forecast has been generated by demand planners, the process entails the release of the forecast from DP to SNP Planners. This is currently performed at FERT level for both Demand Planning and Supply Planning.

The solution will not create additional complication as the forecast release will be still performed at FERT level, but only for the FERT to which all the other SKUs with the shared HALB have been realigned to.

3.6.2 Duplication of forecast results to be avoided

The arisen necessity to ignore the forecast against the products for which the forecast is also performed at a HALB level in the new Planning Area is important to take into consideration.

As the same product will be present in both Planning Areas, it is important that a job is set up to automatically delete the forecast in the first Planning Area at FERT level when the same product is forecasted in the Planning Area at HALB level, in order to avoid duplication of forecast released to SNP.

3.6.3 Decision to load the HALB code as a Navigational Attribute and not as Master Data

A discussion has been raised on the possibility to load the Common Material Code in APO as a Master Data or as a Navigational Attribute.

The option to load it as Master Data was shut down in early stages as it would have had a global impact on the data to be maintained on the Master Data Management system and designated resources would have been necessary for that data maintenance.

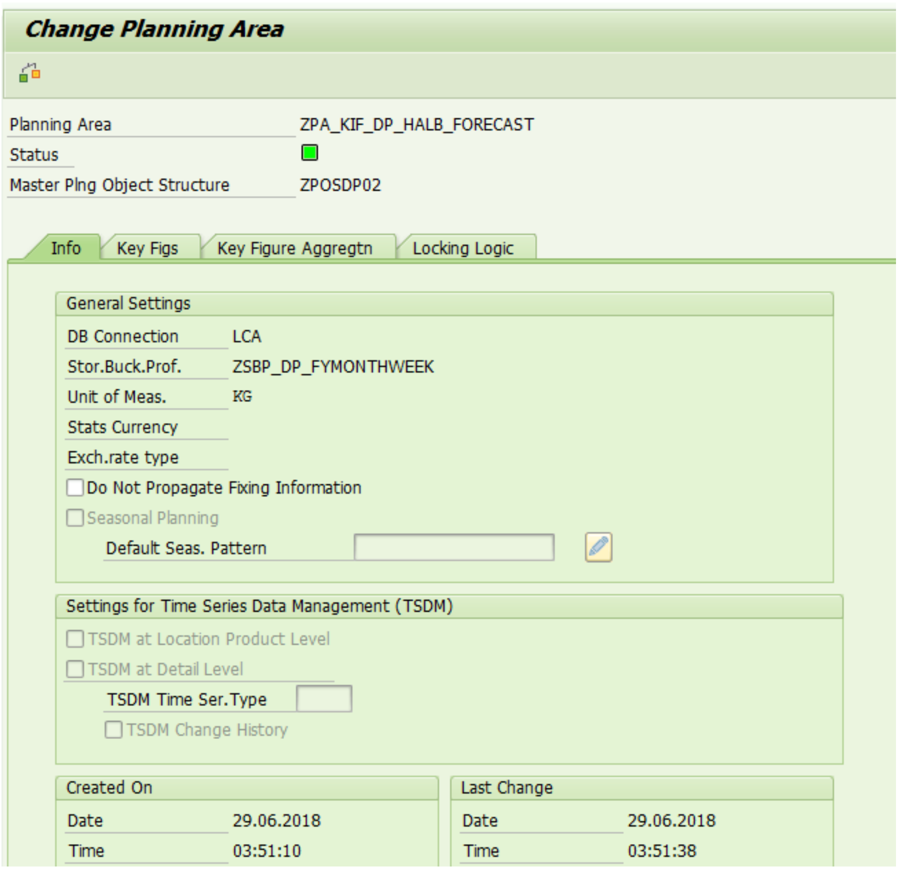
For this reason, the option to load it as a Navigational Attribute has been selected as less invasive and for the easiness of use. Moreover, this last solution is a safer choice in term of possibility to intervene in case an error arises on data, as once the error is found and amended it is automatically amended in the planning book as well.

4 THE IMPLEMENTATION

4.1 PLANNING AREA AND MASTER PLANNING OBJECT STRUCTURE

In order to implement the solution, a new Planning Area has been created in addition to the existing Planning Area for forecasting at FERT level.

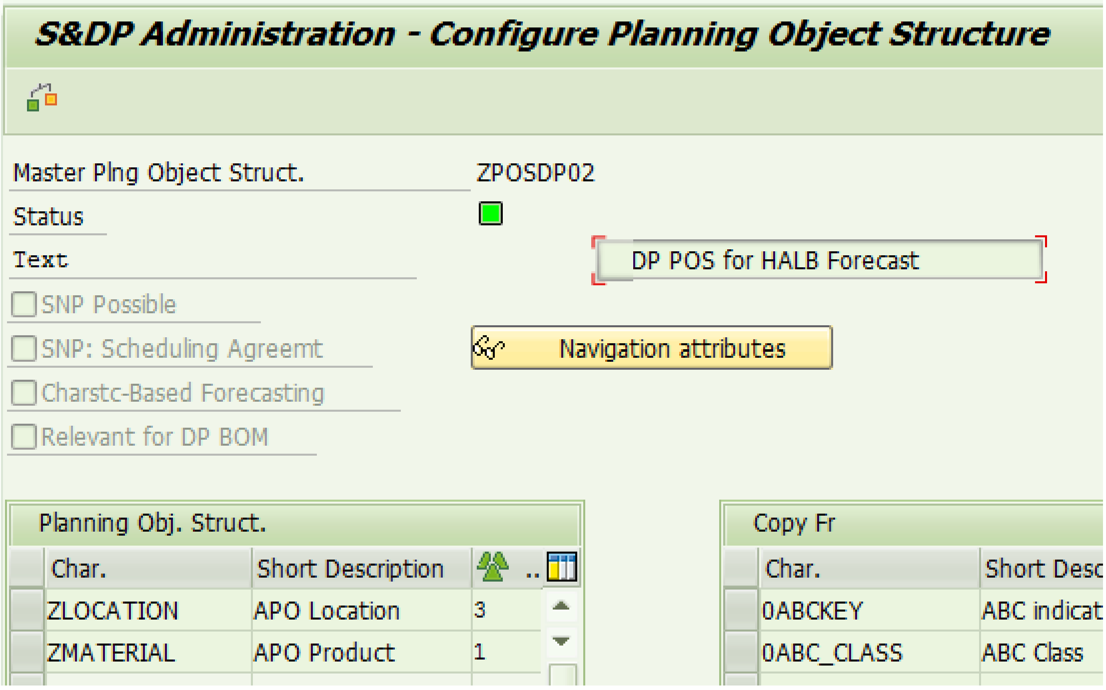
The new Planning Area has been named ZPA_KIF_DP_HALB_FORECAST and it is configured similarly to the initial Planning Area with some differences in term of MPOS that will be listed below.



The MPOS to which it refers to has been also created and it is called ZPOSDP02.

The MPOS, in this case, contains only two Characteristics:

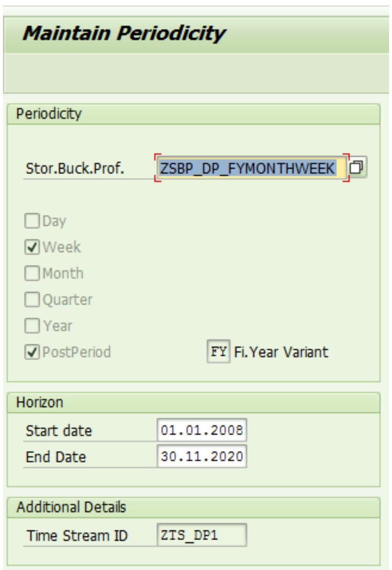
- ZMATERIAL
- ZLOCATION



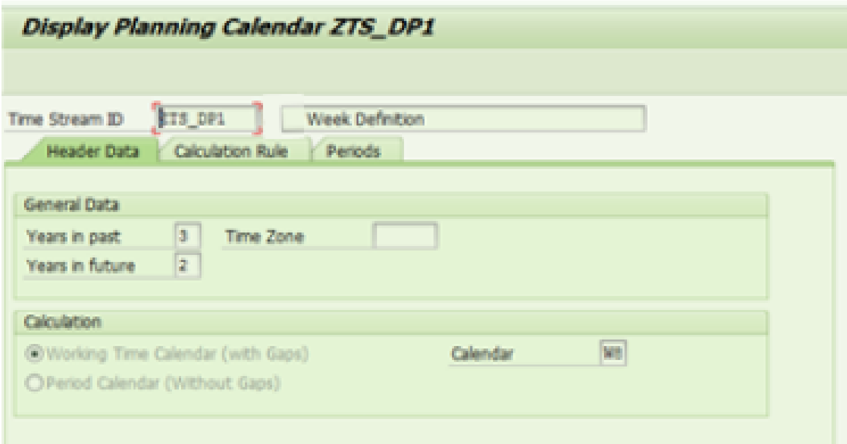
4.2 Storage Bucket Profile

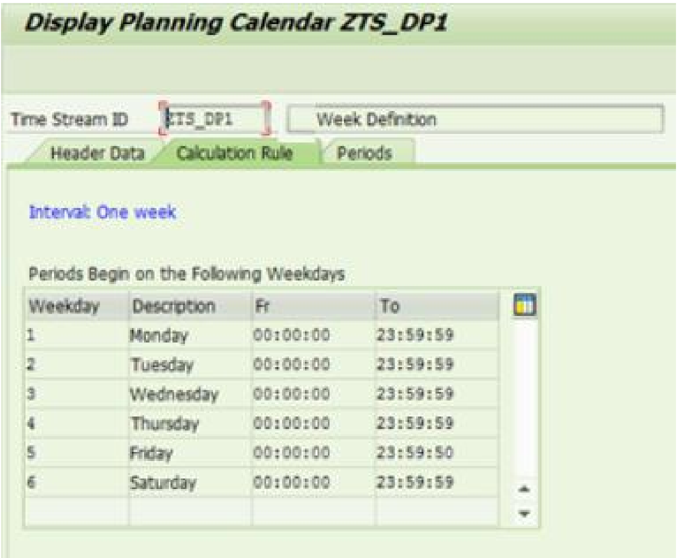
The Storage Bucket Profile used for the Planning Area is ZSBP_DP_FYMONTHWEEK. Because a Storage Bucket Profile defines the time bucket in which data is saved on a Planning Area, in this case data will be stored in weekly buckets.

Also, the Fiscal Year has been selected.



TIME STREAM ID: ZTS_DP1





4.3 Navigation Attributes

A new InfoObject was added to the existing list of Navigational Attributes and it is the Common Base Code.

- Super Group
- Core Technology
- Classification ABC
- Classification XYZ
- Classification LMN
- Common Base Code

Thanks to this decision, no reinitialization of the Planning Area was needed, which means reduced risk and effort with no impact on the current Planning Area that is used globally.

4.4 Planning Book/Data Views

The Planning Book for Demand Planning within the new Planning Area reflects the one present in the Planning Area for forecast at FERT level and is listed below along with the Data Views present inside the Planning Book.

ZPB_DP_01DP_HALB

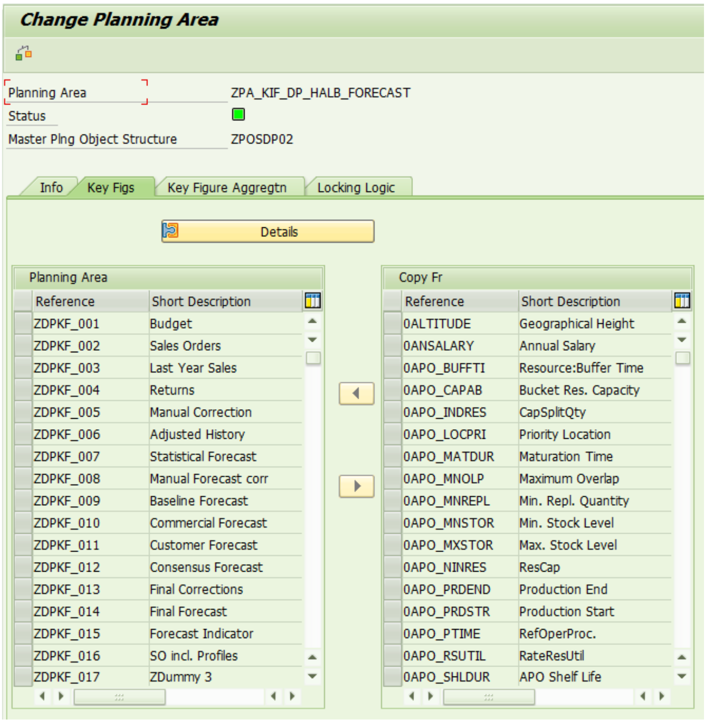
- ZDV_01GEN DP HALB FM
- ZDV_01GENERAL HALB W
- ZDV_03FCST HALB W
- ZDV_04DISAGGREGATION

4.5 Key Figures

The Key Figures have been maintained as in the FERT Planning Area and are also listed below.

- Sales Orders
- Last Year Sales
- Returns
- Manual Correction
- Adjusted History
- Statistical Forecast
- Manual Forecast corrections
- Baseline Forecast
- Customer Forecast
- Commercial Forecast
- Consensus Forecast
- Final Corrections
- Final Forecast

- Budget



4.6 KEY FIGURE DISAGGREGATION

4.6.1 Calculation Type

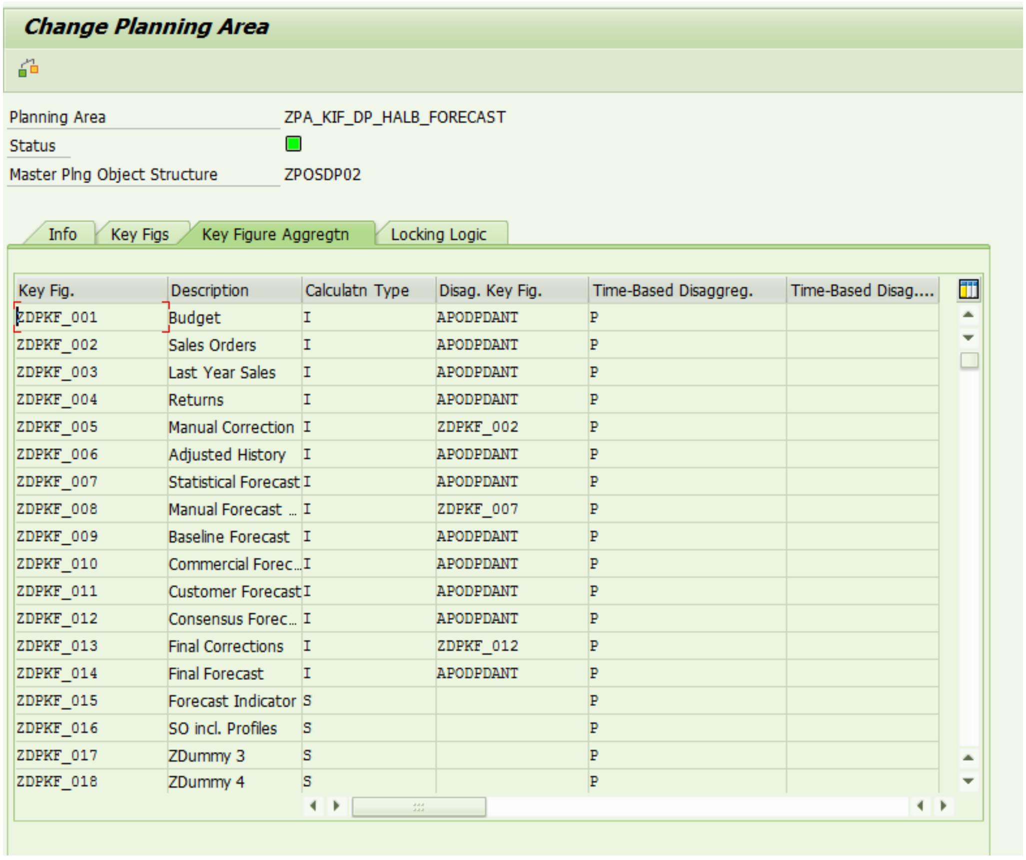
The Key Figures Disaggregation will be made on the base of proportional factors as indicated by the Calculation Type "I". As per SAP definition, this type of calculation distributes the value on detail level in the same proportions as derived from the value of another key figure.

In this case, as required by SAP, it is compulsory to enter APODPDANT as the disaggregation key figure in planning area maintenance.

4.6.2 Time-based disaggregation

This field defines how planning data is disaggregated over a period of time. For this Planning Area, the time-based disaggregation type "P" Proportional distribution has been selected.

This means that the key figure values are distributed in the storage bucket such that subsequently each value of a storage bucket shows the same percentage proportion for the time-based aggregated value as before.



Change Planning Area

Planning Area ZPA_KIF_DP_HALB_FORECAST
Status
Master Plng Object Structure ZPOSDP02

Info | Key Figs | Key Figure Aggregtn | Locking Logic

Key Fig.	Description	Calculatn Type	Disag. Key Fig.	Time-Based Disaggreg.	Time-Based Disag....
ZDPKF_001	Budget	I	APODPDANT	P	
ZDPKF_002	Sales Orders	I	APODPDANT	P	
ZDPKF_003	Last Year Sales	I	APODPDANT	P	
ZDPKF_004	Returns	I	APODPDANT	P	
ZDPKF_005	Manual Correction	I	ZDPKF_002	P	
ZDPKF_006	Adjusted History	I	APODPDANT	P	
ZDPKF_007	Statistical Forecast	I	APODPDANT	P	
ZDPKF_008	Manual Forecast ...	I	ZDPKF_007	P	
ZDPKF_009	Baseline Forecast	I	APODPDANT	P	
ZDPKF_010	Commercial Forec...	I	APODPDANT	P	
ZDPKF_011	Customer Forecast	I	APODPDANT	P	
ZDPKF_012	Consensus Forec...	I	APODPDANT	P	
ZDPKF_013	Final Corrections	I	ZDPKF_012	P	
ZDPKF_014	Final Forecast	I	APODPDANT	P	
ZDPKF_015	Forecast Indicator	S		P	
ZDPKF_016	SO incl. Profiles	S		P	
ZDPKF_017	ZDummy 3	S		P	
ZDPKF_018	ZDummy 4	S		P	

4.7 CHARACTERISTIC VALUES COMBINATION

For this Planning Area, the only Characteristics Values that will be loaded are the one referring to the Material and the Location.

4.8 SELECTION ID

Selection IDs are used to quickly display in the Planning Book a selection of codes the user configured.

For the purpose of the enhancement, the user will be in charge of maintaining its Selection IDs so that all the FERT codes linked to the same HALB will be stored together and he will be able to load only the relevant FERT/HALB for the forecast process.

4.9 NEW PROCESS FLOW

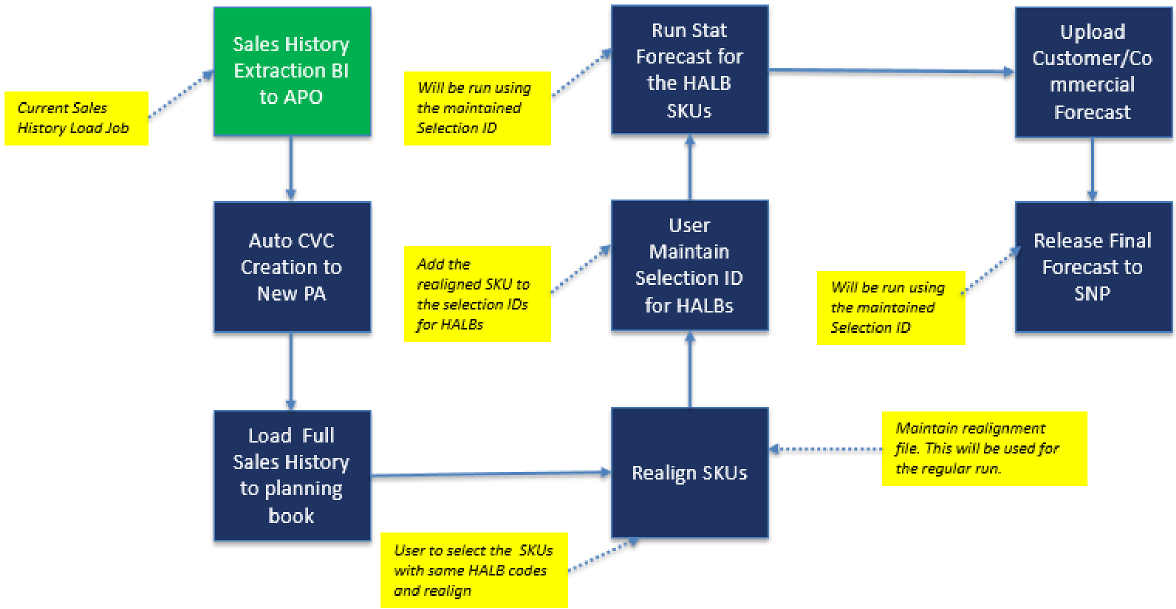


Figure 21 - High Level Process Flow: Initial Load

The sales history extraction is done on a weekly basis as per previous process. The difference will be that the Common Material Code will be included in the fields that the BI Extractor extracts from ECC and loads to the InfoCube in APO. From the history load, the CVCs automatically created will flow in both the Planning Area equally.

It is important to notice that in the initial load the full history will be loaded to the new planning book, process that will differ from the one in place after the initial load.

After the load, the user will be then requested to realign the FERTs (SKUs) codes with the correspondent HALB code. The realigned FERTs will be maintained in the Selection IDs that the user created. Therefore, if we take for example a case in which five FERT codes will be realigned with one common HALB code, the Selection ID will initially display the five FERT codes and after the realignment only the one HALB code.

The realignment will also imply the fact that all the data coming from the five FERTs will be summed up to the HALB code and reflected only on one designated FERT code. This is crucial as it allows the forecast to be released still at a FERT level, even if only on one, without widely impacting the other functions.

In the table below, it is possible to notice that one FERT has the same code as the HALB, “100”.

HALB	FERT	Sales History
100	100	10 kg
100	200	20 kg
100	300	30 kg

The sales history of FERT “100” along with the one from “200” and “300” will be loaded all against the FERT “100”, in this case, 60 kg.

HALB	FERT	Sales History
100	100	60 kg

The other FERT codes will be ignored when the forecast is released and therefore there will be no planning for requirements against these. The only requirement planning will be against the designated FERT.

Once the initial load is completed, the process will follow the below steps:

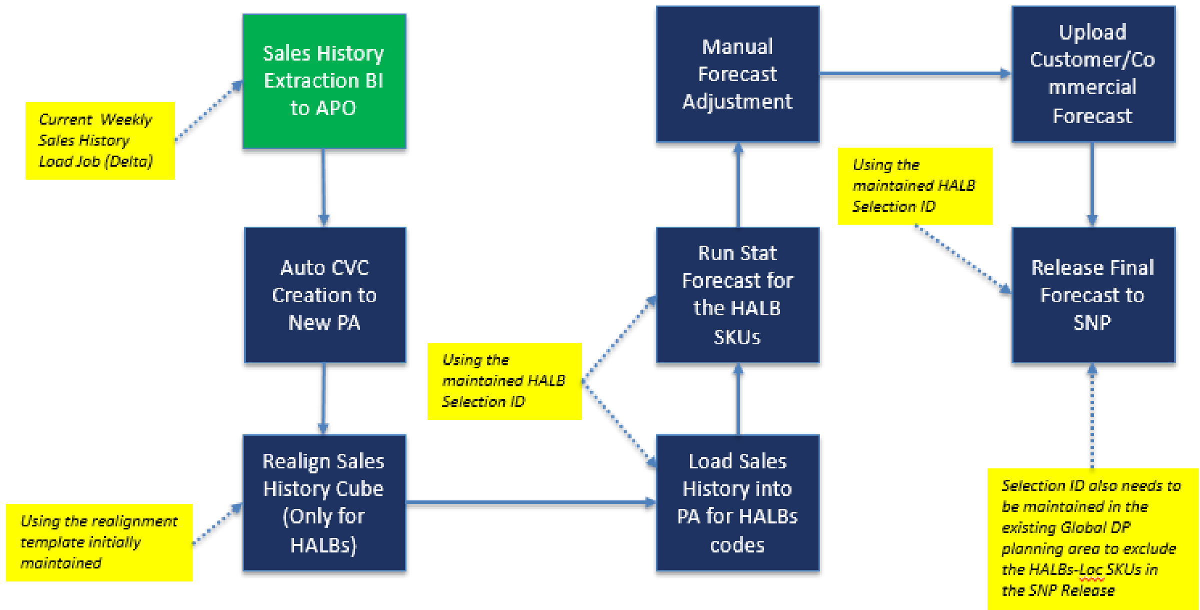


Figure 22 - High Level Process Flow: Proposed Monthly Run

The sales history will still be extracted in the same way as the initial load and the CVCs created with the same fashion, but the Sales History will be loaded on the InfoCube for forecasting at HALB level in a different way.

A realignment file will be uploaded in the APO directory so that every time the Sales History load is made the FERTs are realigned with the correct HALB and flow directly to the Planning Book.

5 CASE STUDY, PROOF OF CONCEPT, FINDINGS AND RECOMMENDATIONS

5.1 OBJECT OF THE CASE STUDY

As the enhancement implemented needs to go through a process of transport from the test environment to the Live environment, for the moment this thesis will only provide a proof of concept to the reader so that the expected result of the solution can be shown.

The object of the case study is six FERT codes within the flavour product hierarchy from the same Production Plant that are sharing the same HALB code. These codes are classified as "A" in the ABC analysis. The list of the codes is provided below:

FERT Code	Plant
A	100
B	100
C	100
D	100
E	100
F	100

As expected on an analysis of the demand history for each of the FERT, the result is a demand that is sporadic and volatile.

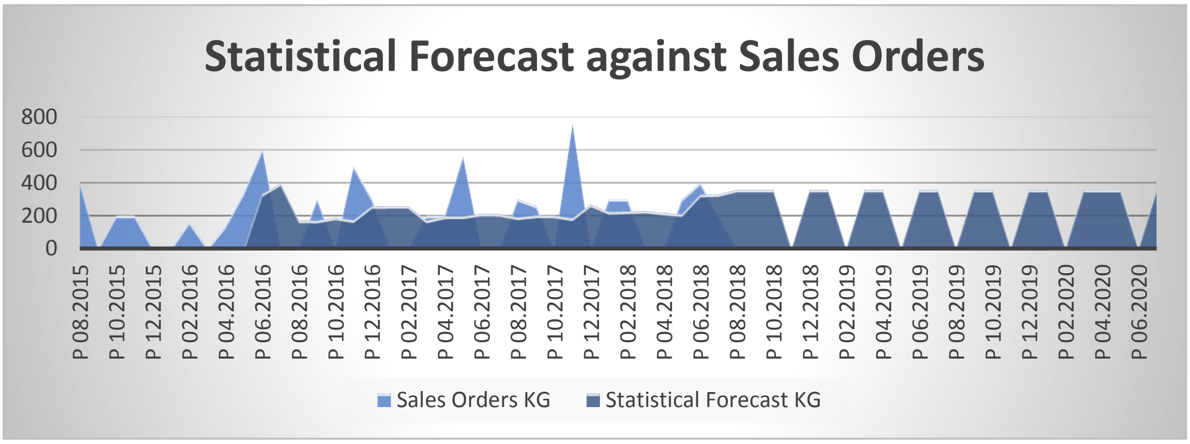
The Statistical Forecast and Final Forecast results will be analysed to show the discrepancies and the inaccuracy against the actual sales that persist with the current process.

FERT code "E" is analysed for the purpose of demonstration. The analysis of the other FERT codes can be found in Appendix.

On the X-axis, the time is referred to the month and the year. For example, "P 08.2015" corresponds to the month of August 2015. The reference table with the Sales and Forecast data can be found in the Appendix.

As it is possible to notice in the following charts, the peaks and valleys are very evident. During peaks, a high risk of stock-out is present and during valleys a greater amount of stock that what is actually needed is kept and therefore costs are higher than necessary. This behaviour is present both in the case of Statistical forecast and Final forecast.

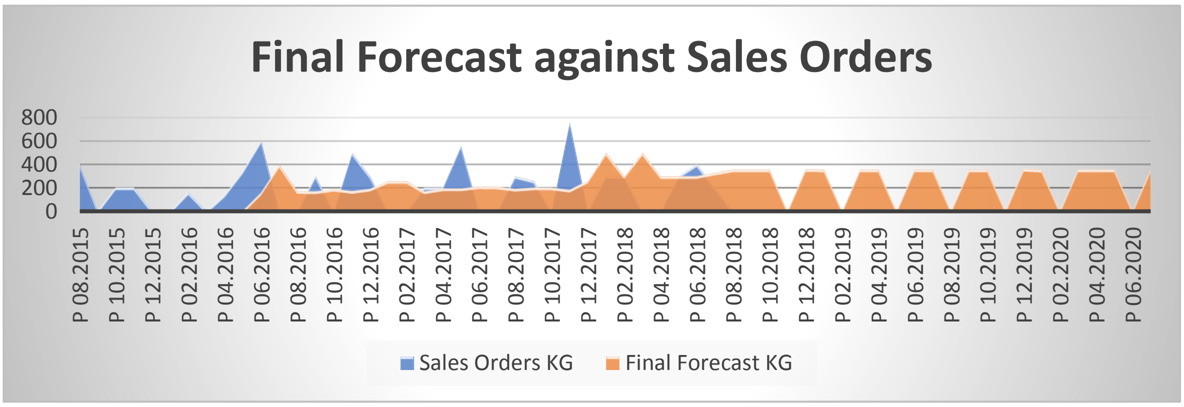
5.1.1 Statistical Forecast result



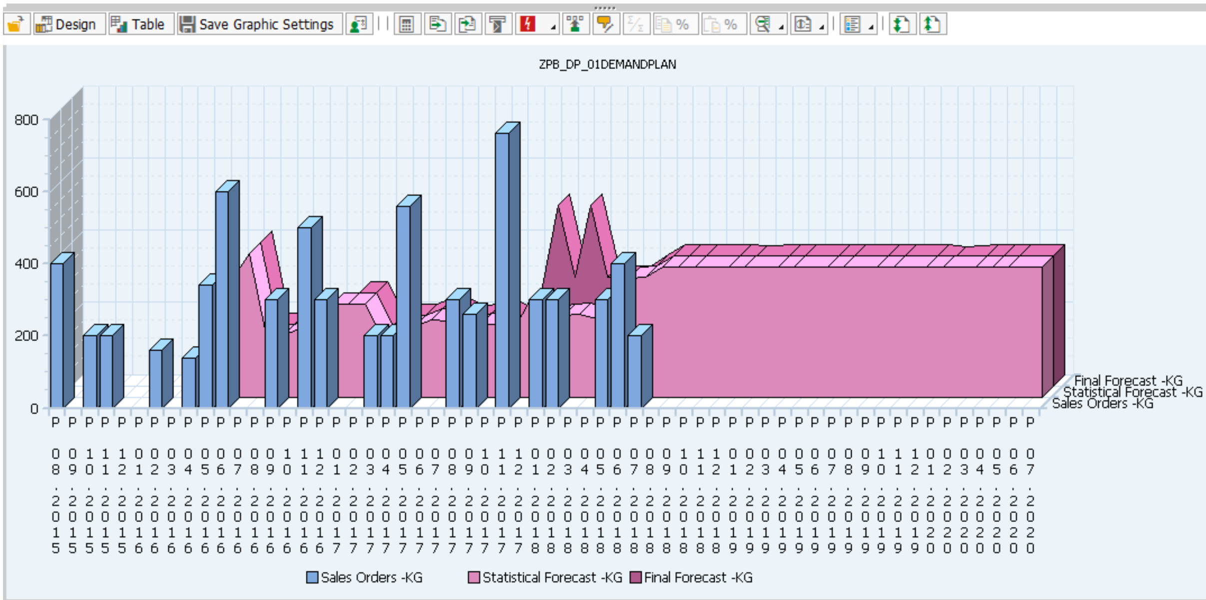
5.1.2 Final Forecast Result

The Final Forecast, that is the result obtained once the Statistical Forecast has been enriched with commercial and customer inputs, should display a value ideally closer than the Statistical Forecast to the actual sales orders.

As it is possible to see in the graph below, the reality is that the Final Forecast it is carrying an error that is even greater than the Statistical Forecast, especially for the period from P12.2017 to P04.2018. This suggests that the Demand Planners encounter huge difficulties or are not provided with useful intelligence with the actual process to correctly forecast demand.



In this 3D view we can have a holistic overview of the Sales Orders, Statistical Forecast and Final Forecast.



5.2 Analysis of statistical and final forecast results through Forecast Accuracy KPIs

There can be various indicator to measure forecast accuracy. The most significant that will be used for the purpose of this enhancement is the Mean Absolute Percentage Error.

5.2.1 Mean Absolute Percentage Error (MAPE)

The MAPE is used to calculate an average error in the forecast across a group of items.

In order to calculate it, it is necessary to sum up all the absolute errors across all items and divide this sum by the actual quantity of sales entered.

The MAPE is defined as sum of all errors divided by the sum of actual sales.

The Error is calculated as

$$Error(i) = Forecast(i) - Actual(i)$$

The Absolute Error is calculated as an absolute value

$$Absolute\ Error(i) = |Error(i)|$$

The Total Error is calculated as

$$Total\ Error = \sum(Absolute\ Error(i)) = 1370\ kg$$

The Error (%) is calculated as

$$Error\ (\%) = \sum\left(\frac{Absolute\ Error(i)}{Actual(i)}\right) * 100$$

The MAPE, which corresponds to the Total Error (%) is calculated as

$$MAPE = Total\ Error\ (\%) = \sum\left(\frac{|Forecast(i) - Actual(i)|}{Actual\ (i)}\right) * 100$$

$$MAPE = Total\ Error\ (\%) = \frac{1}{n}\sum\left(\frac{Error(i)}{Actual(i)}\right) * 100$$

$$Forecast\ Accuracy\ (\%) = 1 - Total\ Error\ (\%) = 1 - MAPE$$

5.2.1.1 Statistical Forecast MAPE

The data contained in the following tables refers to the period P01.2018 and are measured in kg.

	statistical forecast	Sales Orders	Error	Absolute Error	Error %	Forecast Accuracy %
A	800	0	800	800	100%	0%
B	66	100	-34	34	34%	66%
C	12	20	-8	8	40%	60%
D	101	0	101	101	100%	0%
E	221	300	-79	79	26%	74%
F	473	1,300	-827	827	64%	36%
TOTAL	1673	1,720 KG		1849		
MAPE					61%	
Accuracy						39%

5.2.1.2 Final Forecast MAPE

As the following table shows, the error with this forecast is much greater, leading to understand that either the statistical model adopted for the data distribution is not correct or the market intelligence provided to Demand Planners is not accurate.

	Final Forecast	Sales Orders	Error	Absolute Error	Error %	Forecast Accuracy %
A	200	0	200	200	100%	0%
B	66	100	-34	34	34%	66%
C	12	20	-8	8	40%	60%
D	101	0	101	101	100%	0%
E	500	300	200	200	67%	33.33%
F	473	1,300	-827	827	64%	36.40%
TOTAL	1,352	1,720		1370		
MAPE					68%	
Accuracy						32%

Summarizing, the decrease in Final Forecast accuracy could be due to:

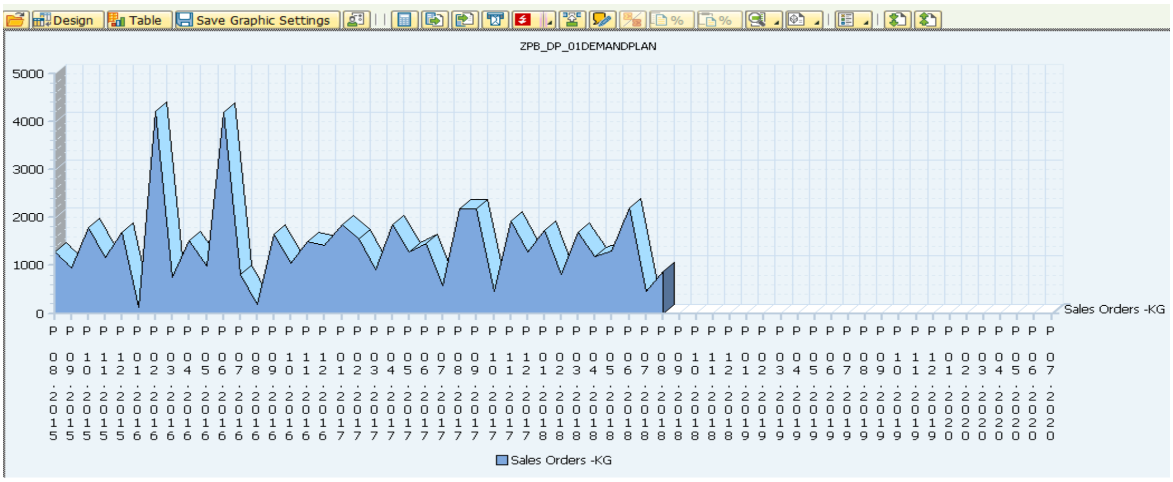
- Incorrect statistical model applied
- Commercial forecast not able to foresee the correct movement in the market
- Customer forecast provided not present of not insightful enough to correctly understand demand, suggesting a tighter collaboration with customers and incentives for it should be needed.

5.3 FERT REALIGNMENT WITH THE HALB

When the FERT realignment is performed, it is possible to notice that the overall demand becomes more predictable. The data in relation to all the FERTs sharing the same HALB will be all aligned to the one designated FERT.

The following table shows the FERT realignment for the periods from P01.2018 to P03.2018. For the complete data set, please refer to Appendix.

GENERAL-FISCAL MONTH	Unit	P 01.2018	P 02.2018	P 03.2018
Sales Orders	kg	1720	820	1680
SO incl. Profiles	kg			
Last Year Sales	kg	1840	1560	900
Returns	kg			
Manual Correction	kg			
Adjusted History	kg	1720	820	1680
Statistical Forecast	kg	1673	1482	1082
Manual Forecast corrections	kg			
Baseline Forecast	kg	1673	1482	1082
Customer Forecast	kg	0	0	0
Commercial Forecast	kg	700	300	700
Consensus Forecast	kg	1352	1557	1380
Final Corrections	kg			
Final Forecast	kg	1352	1557	1380
Budget	kg	1834	1841	1834



5.4 AUTOMATIC MODEL SELECTION

In order to demonstrate the forecast MAPE improvement after the realignment, the forecast model “Automatic Model Selection Procedure 2” has been used (forecast strategy 56).

This forecast strategy is part of the Adaptive Forecasting techniques, which means that background process tests the data set to understand what the best forecasting profile is.
Once the best model has been selected, the test performs an optimisation of the parameters alpha, beta and gamma that minimise the Mean Absolute Deviation (MAD). The combination with the lowest MAD associated is finally selected.
To further finetune the strategy, it is possible to determine a threshold for the MAD over which the system is automatically prompts to start again the automatic model selection and find a new optimal forecast model and parameters for the data set.
The prerequisite for the use of this model are that at least three periods of historical value and two seasonal cycles need to be present at the time the Automatic Model Selection Procedure 2 is performed.

5.4.1 Mean Absolute Deviation (MAD)

Mean Absolute Deviation (MAD) calculated the average distance between each value and the mean.

$$MAD = \frac{1}{n}\sum_{k=1}^{n} |x(i) - \bar{x}|$$

In SAP APO, it is calculated by the absolute difference between the ex-post forecast and the actual value.
Before testing all the models, the system first tests for intermittent historical data by determining the number of periods that do not contain any data in the historical key figure. If this is larger than 66% of the total number of periods, the system automatically stops model selection and uses the Croston Method.
As expected, this applies to the scenario of the Case Study. The result of the Automatic Model Selection Procedure 2 has been the Croston Method.

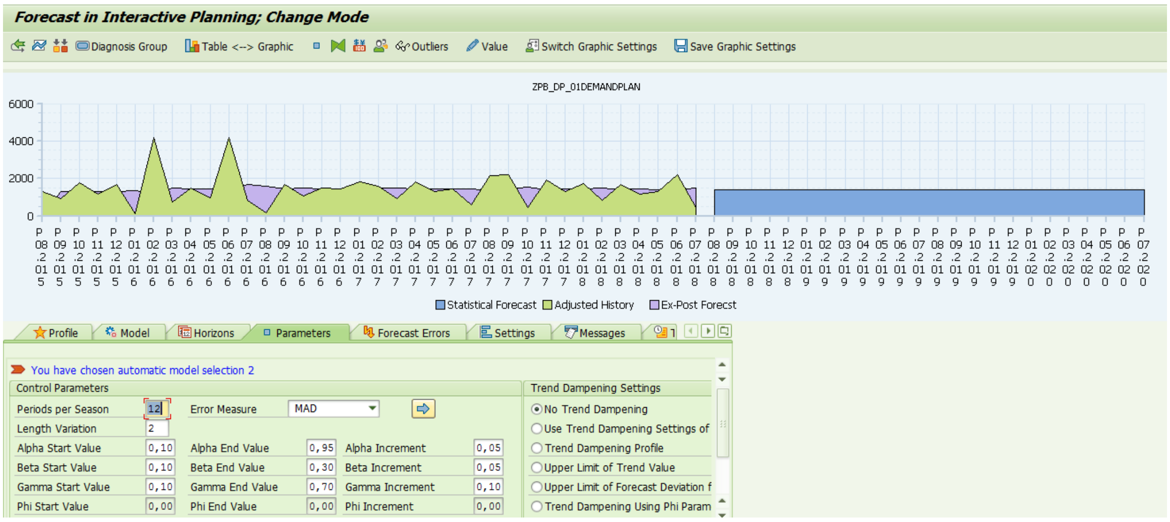


Figure 23- Configuration of setting for Automatic Model Selection 2

5.4.1.1 Croston Method

This forecast strategy (80) is used mainly when a product shows intermittent demand.

This method consists of two steps:

1. Separate exponential smoothing estimated are performed on the average size demand.
2. The average interval between demands is calculated. This will be used to predict the future demand in the form of a constant model.

The fact that Croston methods deals independently with the demand volume and the inter-demand intervals is an advantage compared to other methods such as moving average or simple exponential smoothing.

5.4.1.2 Initialisation

The system checks the first time-bucket of the historical values.

- If it finds a value (not zero), it gives Z this as its initial value. X is set to 1.
- If it does not find a value, Z is set to 1, X to 2.

V(t) = Historical Value

P(t) = Forecasted Value

Q = interval between last two periods with demand

α = Smoothing factor for the estimates

Z = Estimate of demand volume

X = Estimate of intervals between demand

If 1st value ≠ → Z(0) = V(1), X(0) = 1

If 1st value = → Z(0) = V(1), X(0) = 2

5.4.1.3 Calculation of Forecast Parameters

The forecast model is performed by modifying the constant model. The parameters used for the model are P and X and they are determined as below:

If V(t) = 0

q = q + 1

Else

Z(t) = Z(t-1) + α[V(t) – Z(t-1)]

X(t) = X(t-1) + α[q – X(t-1)]

Endif

The equation Z(t) = Z(t-1) + α[V(t) – Z(t-1)] corresponds to the calculation of the non-zero demand, while the equation X(t) = X(t-1) + α[q – X(t-1)] is the calculation of the inter-demand intervals.

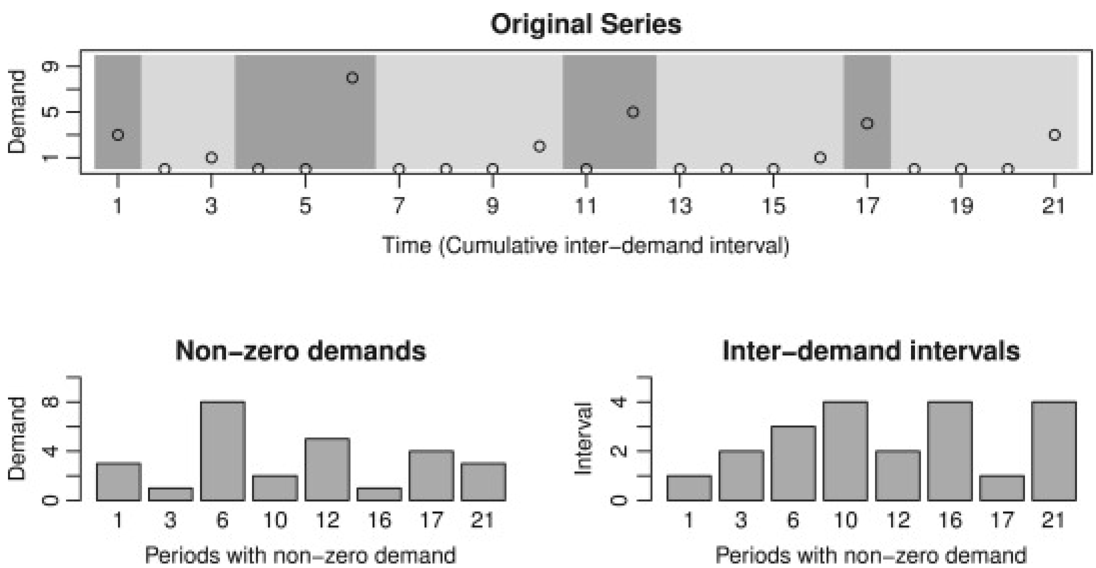


Figure 24 Calculation of non-zero demands and non-zero intervals with Croston model

The last iteration for the last time bucket returns the parameters Z(f) and Z(f).

5.4.1.4 Forecast

Two forecast results are possible for the Croston Model

1. The forecast quantity is distributed over all time buckets equally across all the forecast period.
2. The forecast quantity is distributed according to the mean interval X that the system determined earlier

If t=n.X+1

P=Z(f)

Else

P=0

*End*if

The two results are illustrated below:

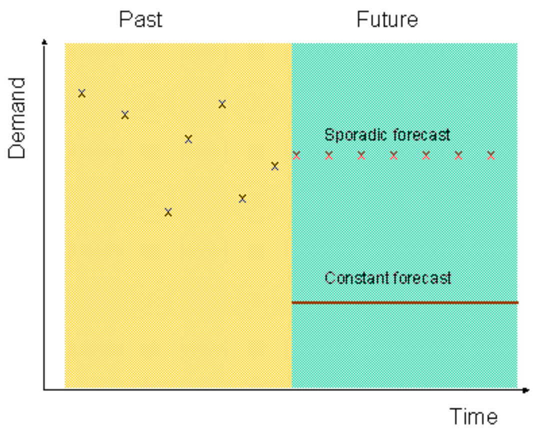
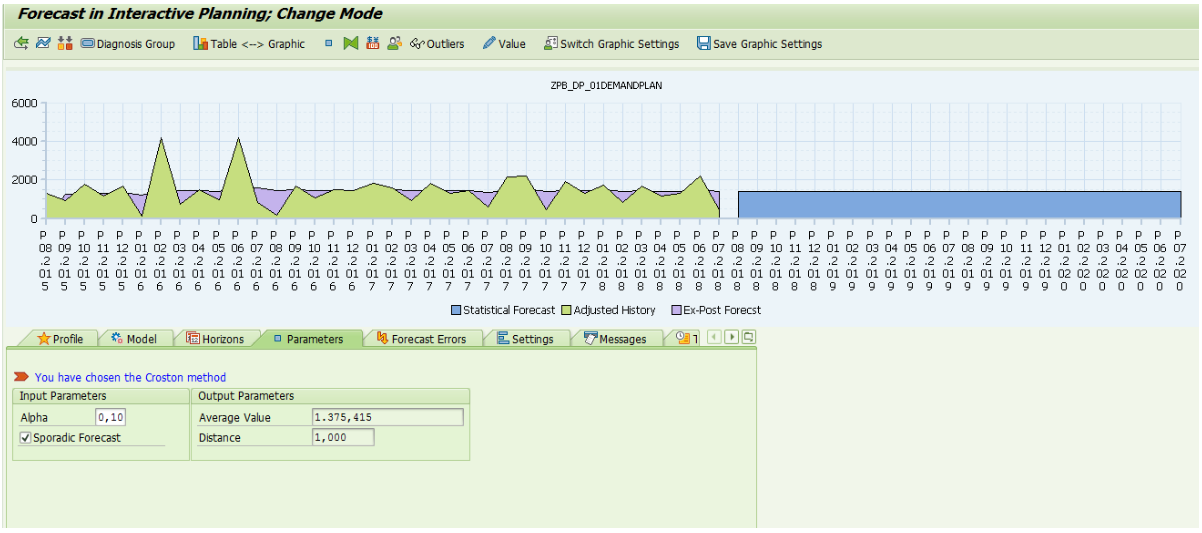
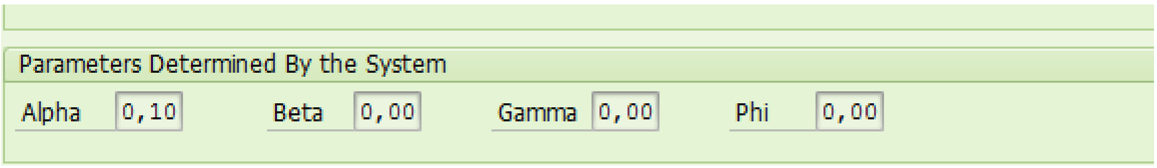


Figure 25- Forecast results with Croston model

For the Case Study, the first result has been selected over the second. As the reader can see in the graphic below, the forecast is distributed over the various time buckets equally.



The Alpha factor that smooth the basic value used is 0.10.



The Average Value of the Historical Series is 1.375,415.

The Distance between Historical Value Periods is 1,000.

5.4.2 What-If Analysis

A what-if analysis has been performed on the Alpha factor to prove that and α= 0.10 generates the minimum MAPE.

Generally speaking, a Alpha factor should be always between 0.1 and 0.3, depending on the model selection. Usually for Crostom model it is set around 0.2.

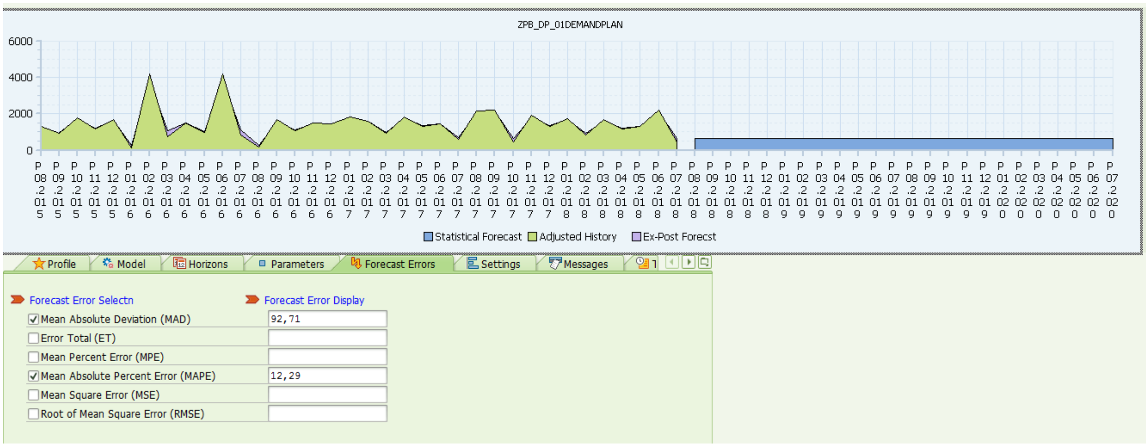
The Alpha factor allows to give more weight to the most recent values while the older values are exponentially wheighted less.

It is necessary to point out that also an α=0.5 has generated the same result in term of MAPE.

The results of the analysis are shown below:

Alpha Factor	Mean Absolute Deviation (MAD)	Mean Absolute Percent Error (MAPE)
0.01	565.35	78,16
0.1 and 0.5	371.13	55.04
0.2	516.65	76,26
0.3	472,31	70.77

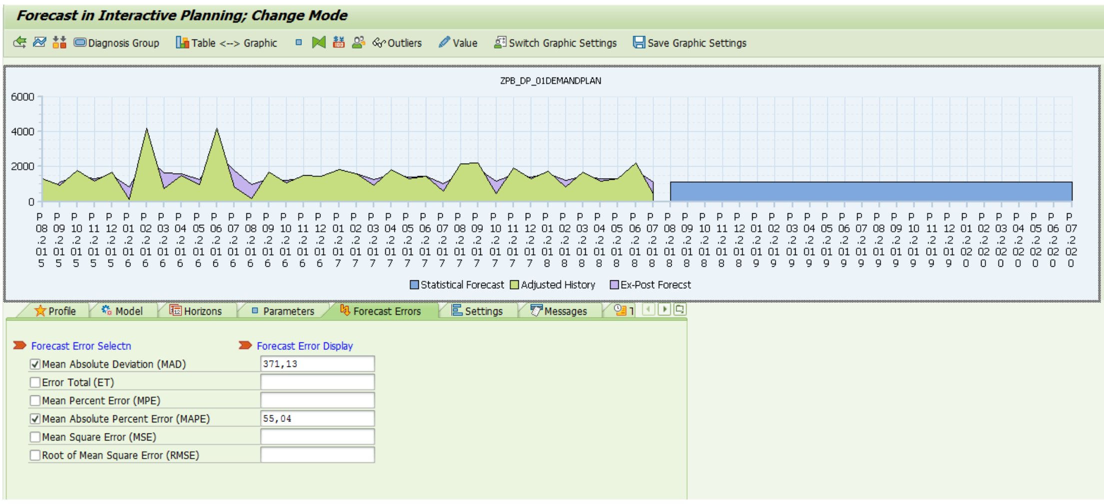
For alpha greater than 0.5, the following result has been obtained:



This happens because higher Alpha values are more sensitive to random spikes in the history of sales but the forecast for future periods will then reflect more the past history of sales rather than the recent history, which it is generally speaking a more valuable information.

The Forecast error indicators returned for the selection are:

- MAD = 371,13
- MAPE = 55,04



In this way the MAPE is 55.04% that is lower than 68% average MAPE obtained with the current forecast process.

This improvement shows that there are still difficulties in forecasting flavours FERTs as the target of 25% MAPE is well away from the achieved one but, overall, it shows that a good improvement is possible.

5.5 Forecast Release

When the final forecast has been prepared and it is ready to be released to the supply planner, the supply planner will be informed that only one FERT holds the forecast of the other codes and he will therefore plan the requirements only against that product.

The planner can also decide whether to produce the FERT already or if to product the HALB only and then stock it and pack it only when the order becomes available.

This involves the utilization of a production strategy that is a hybrid between the MTS and MTO logic, which uses most of the characteristics of the Postponement strategy.

6 CONCLUSIONS

The new process of forecasting the demand at HALB level is expected to bring better performance in terms of Mean Average Percentage Error reduction of the forecast result. The forecast models offered by SAP APO system that can be applied are several and it will be Demand Planner's task to select which is most suitable according to his experience. The assumption is that the historical data loaded to be modelled is accurate. The Croston Method is likely to be the best fit for most of the data set generated by the new process for products within the flavour product hierarchy.

The benefits of using the Croston Method to forecast lumpy demand have long been discussed in the literature. An agreement has not been reached yet but the a lesson learnt from most of the experiences is that demand planning and demand forecasting are essential components of the Demand Management processes and if focus and resources are allocated to them, they can enable the Company to achieve greater performance under several points of view.

In particular, among the factors impacting forecast accuracy resolvable internally by the Demand Management, the solution proposed in this Master Thesis aims to mitigate the demand forecast bias that is one of the main causes of the Bullwhip effect mentioned before. This result is achieved through the data reconciliation and the reduction of demand intermittency and volatility.

The Demand Management will be empowered with the new forecasting solution implemented, but it is also important that, along with this, the Management work on avoiding working in isolation and in silo.

Collaboration with customers and other stakeholders is very important in the forecasting process and it has to happen intra and inter-Company, in order to reduce the insecurity about the orders and any types of overreactions. This will eventually lead to a reduction in the demand amplitude that will have an additional positive effect on the forecast accuracy performance that this project has been trying to improve.

Measurements on the quality of the forecasts provided are also key for a successful Demand Management. The introduction and monitoring of Key Performance Indicators on the Customer

Forecast along with measurement on the forecast itself such as Forecast Accuracy, MAPE, MAD, Consistent Bias (the number of periods a forecast for a certain SKU/Customer combination is above or below the actual result) to understand where intervention is needed will be an important requisite.

In conclusion, while the attention can be conveyed towards a thousand of different KPIs, it is important to consider that reports are backward looking and too much focused on the past, while forecast is about the guidance for the future and what factors are going to affect it.

7 ACKNOWLEDGEMENTS

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Despite being very far away from my family, the remote support and encouragement from them has been invaluable and the strength to keep going despite all the issues faced is a value that they taught me and that I will keep in mind for my future professional life.

Finally, my grateful thanks to my friends James, Soon, Leslie, Kathryn and Hitesh for assisting me in proof reading and tweaking the Thesis and for the daily motivation I received from them at work that plays an important role in performing our day-to-day job.

Giulia Trivellin

APPENDIX

APPENDIX 1

Method	Forecast Strategy		System Action
Constant	Forecast with constant model	10	Uses first-order exponential smoothing. This strategy is identical to strategy 11. See also Constant Model w. First-Order Exponential Smoothing.
Constant	First-order exponential smoothing	11	Uses first-order exponential smoothing. This strategy is identical to strategy 10. See also Constant Model w. First-Order Exponential Smoothing.
Constant	Constant model with automatic alpha adaptation (first-order)	12	Uses first-order exponential smoothing and adapts the alpha factor. See also Constant Model w. First-Order Exponential Smoothing and Automatic Adaptation of the Alpha Factor.
Constant	Moving average	13	The system calculates the average of the values in the historical time horizon as defined in the master forecast profile. This average for n periods of history is the forecast result for each period in the forecast horizon; that is, the forecast is the same in every period. See also Moving Average Model.
Constant	Weighted moving average	14	The system weights each time series value with a weighting factor. For example, you can define the factors so that recent data is weighted more heavily than older data. You define the weighting factor in a diagnosis group. See also Weighted Moving Average Model.
Trend	Forecast with trend model	20	Uses first-order exponential smoothing. This strategy is identical to strategy 21. See also Trend/Seasonal Models w. First-Order Exp. Smoothing.
Trend	First-order exponential smoothing	21	Uses first-order exponential smoothing. This strategy is identical to strategy 21. See also Trend/Seasonal Models w. First-Order Exp. Smoothing.
Trend	Second-order exponential smoothing	22	Uses first-order exponential smoothing. See also Models with Second Order Exponential Smoothing.
Trend	Trend model with automatic alpha adaptation (second-order)	23	Uses second-order exponential smoothing and adapts the alpha factor. See also Models with Second-Order Exponential Smoothing and Automatic Adaptation of the Alpha Factor.
Seasonal	Forecast with seasonal model	30	Uses first-order exponential smoothing. This strategy is identical to strategy 31. See also Trend/Seasonal Models w. First-Order Exp. Smoothing.

Seasonal	Seasonal model based on Winters' method	31	Uses first-order exponential smoothing. This strategy is identical to strategy 30. See also Trend/Seasonal Models w. First-Order Exp. Smoothing.
Seasonal	Seasonal linear regression	35	Calculates seasonal indexes, removes the seasonal influence from the data, performs linear regression, and reapplies the seasonal influence to the calculated linear regression line. See also Seasonal Linear Regression.
Seasonal trend	Forecast with seasonal trend model	40	Uses first-order exponential smoothing. This strategy is identical to strategy 41. See also Trend/Seasonal Models w. First-Order Exp. Smoothing.
Seasonal trend	First-order exponential smoothing	41	Uses first-order exponential smoothing. This strategy is identical to strategy 40. See also Trend/Seasonal Models w. First-Order Exp. Smoothing.
Automatic model selection	Forecast with automatic model selection Test for constant, trend, seasonal, and seasonal trend (model selection procedure 1)	50	Choose this strategy if you have no knowledge of the patterns in your historical data. The system tests the historical data for constant, trend, seasonal, and seasonal trend patterns. The system applies the model that corresponds most closely to the pattern detected. If no regular pattern is detected, the system runs the forecast as if the data revealed a constant pattern. In this process, the alpha, beta, and gamma factors are determined as follows: – The smoothing factors are taken from the univariate profile. – The settings in the demand planning desktop are used if these are different to the ones in the univariate profile. – If you have made no settings either in the univariate profile or on the demand planning desktop, the default factors of 0.3 are used. See also Automatic Model Selection Procedure 1.
Automatic model selection	Test for trend (model selection procedure 1)	51	Choose this strategy if you think that there is a trend pattern in your historical data, and if you know that there is no other pattern. The system subjects the historical values to a regression analysis and checks to see whether there is a significant trend pattern. If not, the system runs the forecast as if the data revealed a constant pattern. The alpha and beta factor is also determined as described under strategy 50 for determining the alpha, beta, and gamma factors.
Automatic model selection	Test for season (model selection procedure 1)	52	Choose this strategy if you think that there is a seasonal pattern in your historical data, and if you know that there is no other pattern. The system clears the historical values of any possible trends and carries out an autocorrelation test. If no seasonal pattern is detected, the system runs the forecast as if the data revealed a constant pattern.

			The alpha and beta factor is also determined as described under strategy 50 for determining the alpha, beta, and gamma factors.
Automatic model selection	Test for trend and season (model selection procedure 1)	53	Choose this strategy if you think that there is a seasonal and/or a trend pattern in your historical data. The system subjects the historical values to a regression analysis and checks to see whether there is a significant trend pattern. It also clears the historical values of any possible trends and carries out an autocorrelation test to see whether there is a significant seasonal pattern. If a seasonal and/or trend pattern is detected, a trend model, seasonal model, or seasonal trend model is used. If no regular pattern is detected, the system runs the forecast as if the data revealed a constant pattern. The alpha, beta, and gamma factor is also determined as described under strategy 50.
Manual model selection with test for an additional pattern	Seasonal model and test for trend (model selection procedure 1)	54	Choose this strategy if you think that there is a trend pattern in your historical data, and if you know that there is a seasonal pattern. The system subjects the historical values to a regression analysis and checks to see whether there is a significant trend pattern. If there is, a seasonal trend model is used. Otherwise, a seasonal model is used. The alpha, beta, and gamma factor is also determined as described under strategy 50.
Manual model selection with test for an additional pattern	Trend model and test for seasonal pattern (model selection procedure 1)	55	Choose this strategy if you think that there is a seasonal pattern in your historical data, and if you know that there is a trend pattern. The system clears the historical values of any possible trends and carries out an autocorrelation test. If the test is positive, a seasonal trend model is used. Otherwise, a trend model is used. The alpha, beta, and gamma factor is also determined as described under strategy 50.
Automatic model selection	Model selection procedure 2	56	Choose this strategy if you wish highly detailed tests of the historical data to be carried out. The system tests for constant, trend, seasonal, and seasonal trend patterns, using all possible combinations for the alpha, beta, and gamma smoothing factors, where the factors are varied between 0.1 and 0.5 in intervals of 0.1. The system then chooses the model with the lowest mean absolute deviation (MAD). Procedure 2 is more precise than procedure 1, but takes longer.
Copy history	Historical data used as forecast data	60	Choose this strategy if demand does not change at all and you want to opt for the least performance- or work-intensive strategy. No forecast is calculated. Instead, the historical data from the previous year is copied.

Manual forecast	Manual forecast	70	Choose this strategy if you wish to set the basic value, trend value, and/or seasonal indexes yourself. See also Manual Forecast.
Croston	Croston Method	80	Choose this method if demand is sporadic. See the *APO Glossary* and Croston Method.
Linear regression	Simple linear regression	94	The system calculates a line of best fit for the equation y = a + bx, where a and b are constants. The ordinary least squares method is used.

APPENDIX 2

Calculation of CAGR:

$$\text{CAGR} = \left(\frac{\text{Ending Value}}{\text{Beginning Value}}\right)^{\left(\frac{1}{\#\text{ of years}}\right)} - 1$$

Time-Based disaggregation:

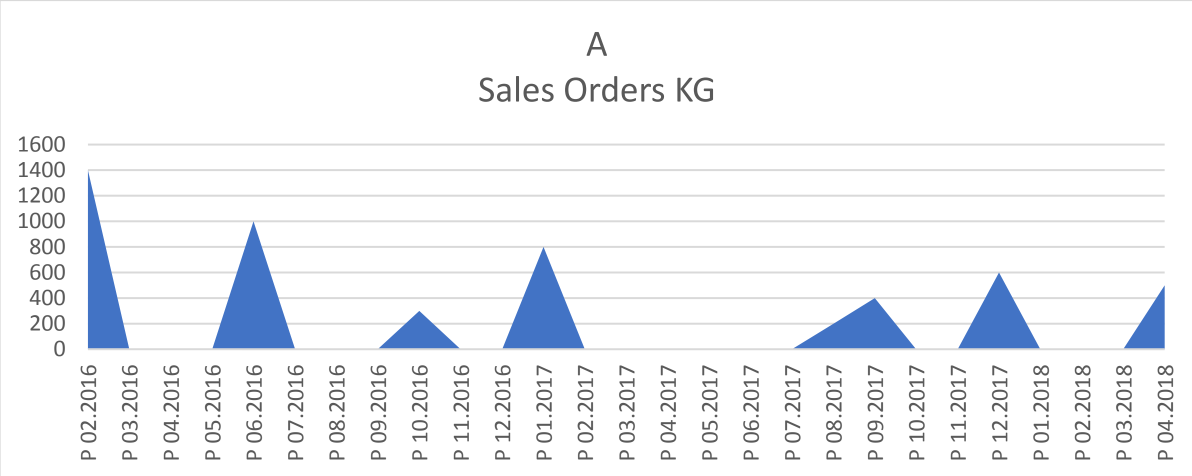
- P - Proportional distribution
- I - Proportional distribution
- E - Equal distribution
- N - No disaggregation in time
- K - Based on another key figure
- L - Read

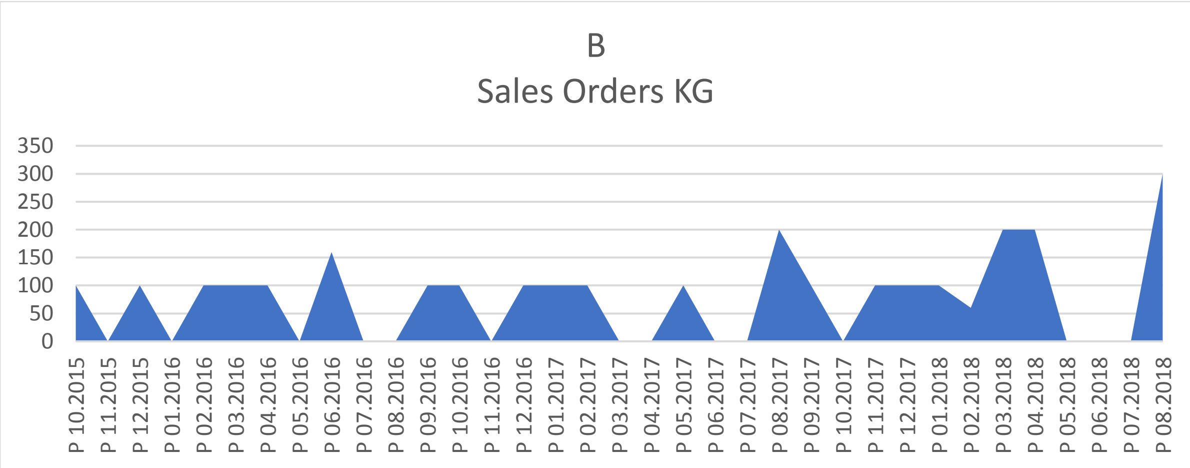
Calculation Types:

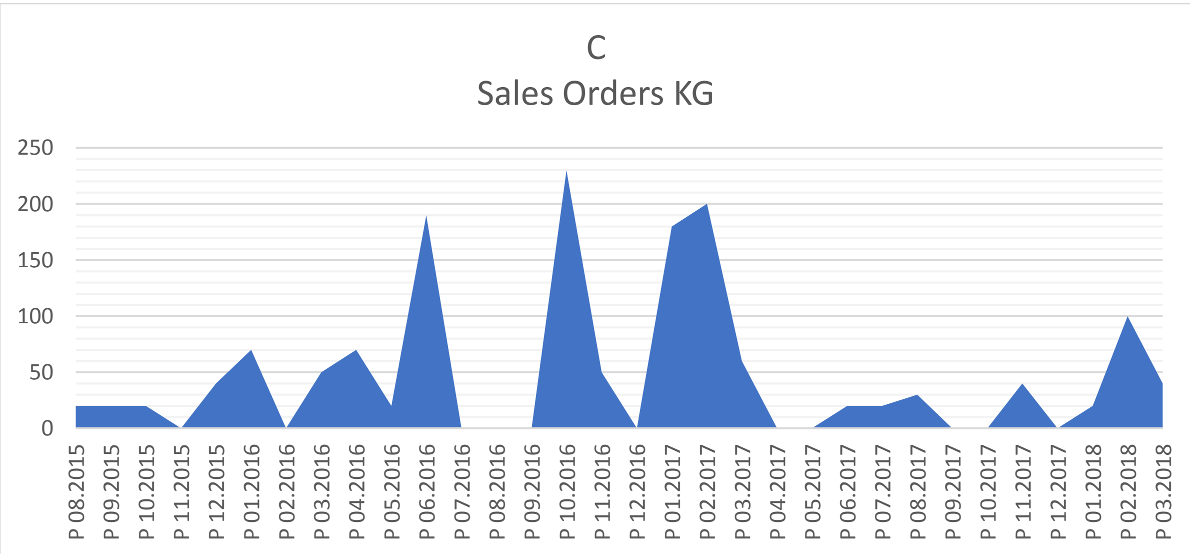
- S - Pro rata
- P - Based on another key figure
- A - Average of key figures
- N - No disaggregation
- I - Pro rata
- D - Average at the Lowest Level of Detail
- E - Average of All Details Not Equal to Zero
- F - Average of lowest level non zero; Disagg. pro Rata

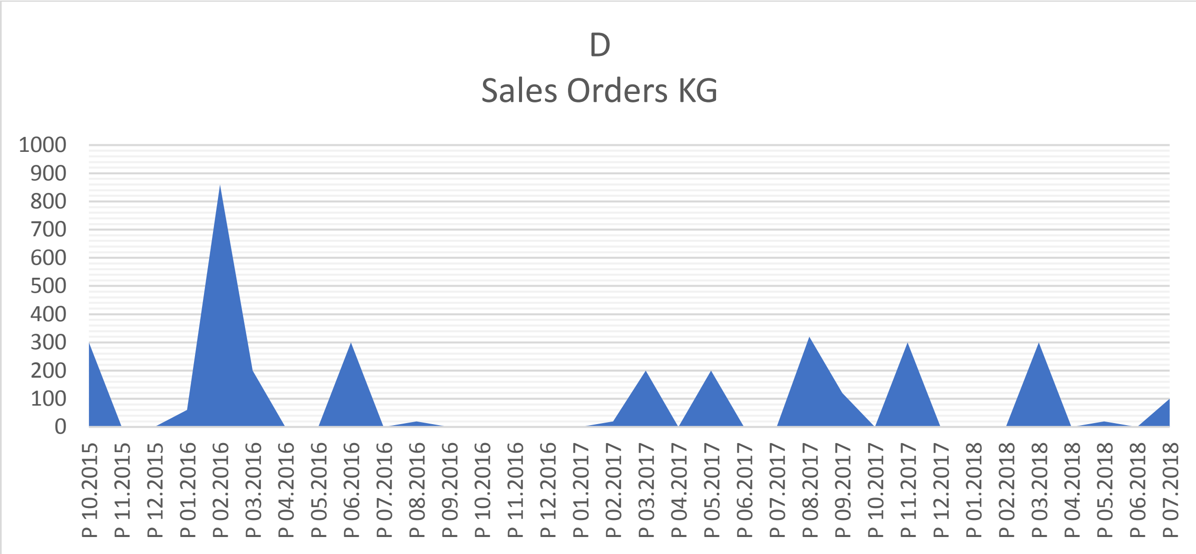
APPENDIX 3

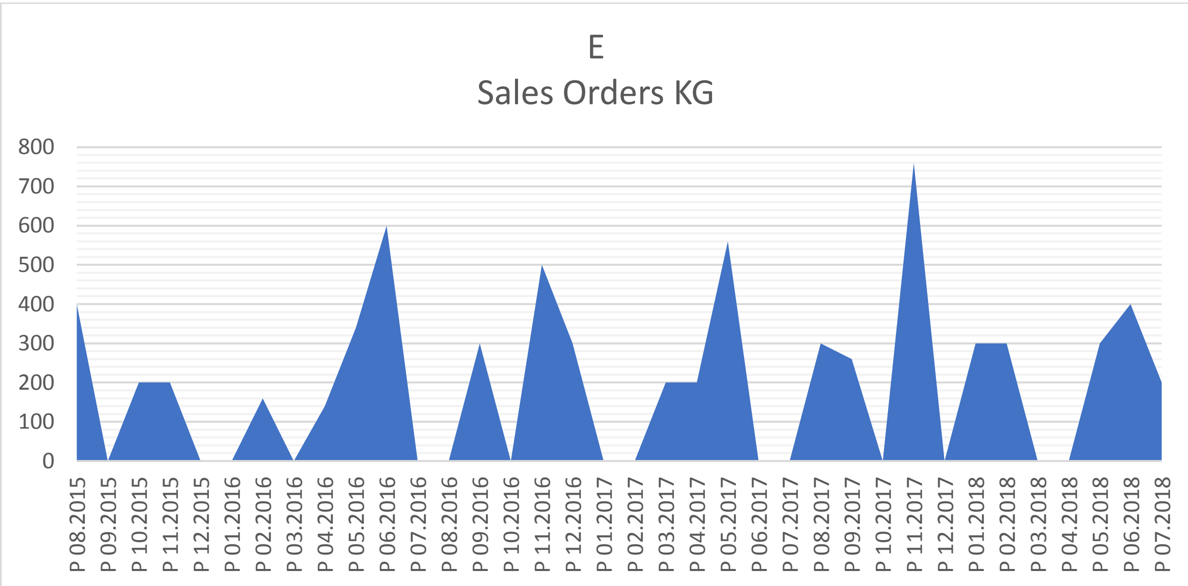
Sales History of FERTs in the Case Study








D
Sales Orders KG
1000
900
800
700
600
500
400
300
200
100
0
P 10.2015
P 11.2015
P 12.2015
P 01.2016
P 02.2016
P 03.2016
P 04.2016
P 05.2016
P 06.2016
P 07.2016
P 08.2016
P 09.2016
P 10.2016
P 11.2016
P 12.2016
P 01.2017
P 02.2017
P 03.2017
P 04.2017
P 05.2017
P 06.2017
P 07.2017
P 08.2017
P 09.2017
P 10.2017
P 11.2017
P 12.2017
P 01.2018
P 02.2018
P 03.2018
P 04.2018
P 05.2018
P 06.2018
P 07.2018


E
Sales Orders KG
800
700
600
500
400
300
200
100
0
P 08.2015
P 09.2015
P 10.2015
P 11.2015
P 12.2015
P 01.2016
P 02.2016
P 03.2016
P 04.2016
P 05.2016
P 06.2016
P 07.2016
P 08.2016
P 09.2016
P 10.2016
P 11.2016
P 12.2016
P 01.2017
P 02.2017
P 03.2017
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P 05.2017
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P 07.2017
P 08.2017
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P 12.2017
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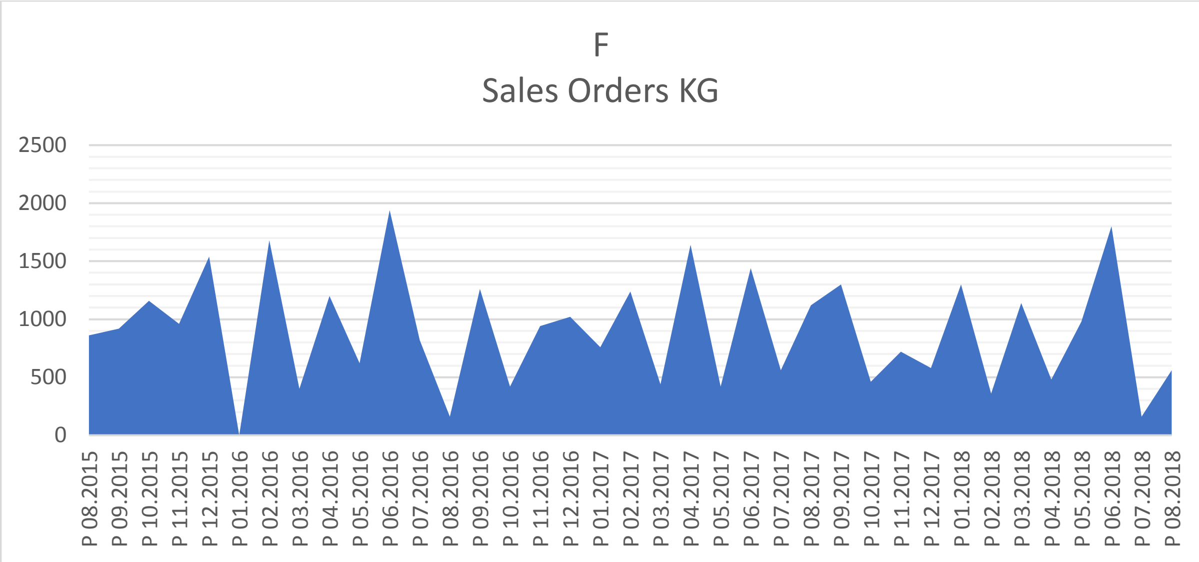
P 06.2018
P 07.2018


F
Sales Orders KG
2500
2000
1500
1000
500
0
P 08.2015
P 09.2015
P 10.2015
P 11.2015
P 12.2015
P 01.2016
P 02.2016
P 03.2016
P 04.2016
P 05.2016
P 06.2016
P 07.2016
P 08.2016
P 09.2016
P 10.2016
P 11.2016
P 12.2016
P 01.2017
P 02.2017
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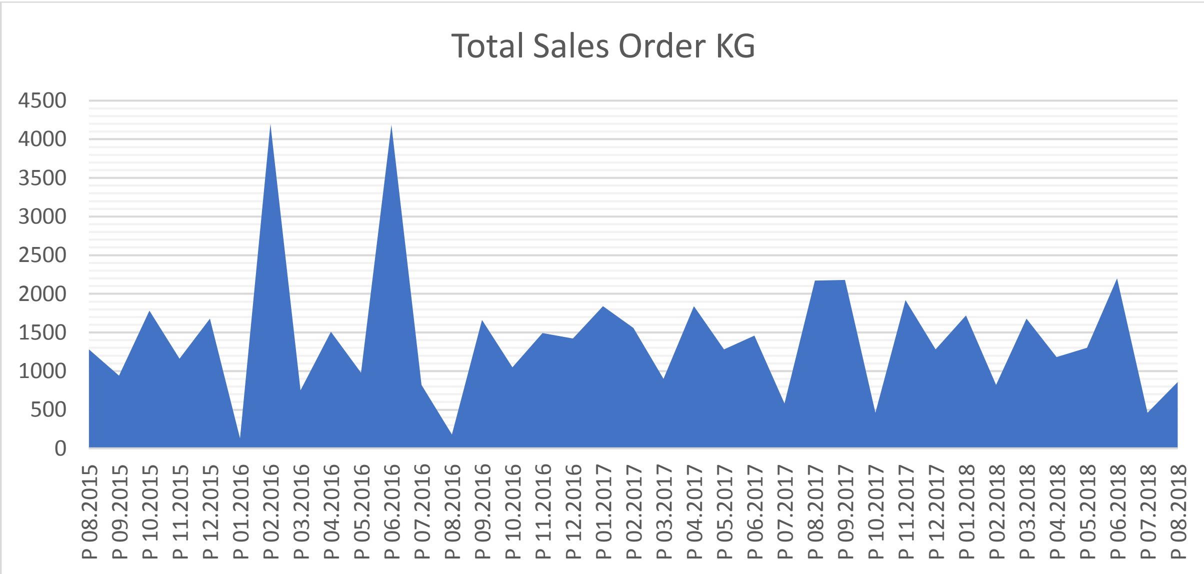
P 08.2018


Total Sales Order KG
4500
4000
3500
3000
2500
2000
1500
1000
500
0
P 08.2015
P 09.2015
P 10.2015
P 11.2015
P 12.2015
P 01.2016
P 02.2016
P 03.2016
P 04.2016
P 05.2016
P 06.2016
P 07.2016
P 08.2016
P 09.2016
P 10.2016
P 11.2016
P 12.2016
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P 09.2017
P 10.2017
P 11.2017
P 12.2017
P 01.2018
P 02.2018
P 03.2018
P 04.2018
P 05.2018
P 06.2018
P 07.2018
P 08.2018

Automatic Model Selection Procedure 2

	White Noise Test	Sporadic Data Test	Seasonal Test	Trend Test
Croston Model		x		
Trend model				x
Seasonal model			X	
Seasonal trend			A	A
Linear regression			O	X
Seasonal linear regression			A	A

X – The model is used if the test is positive

A – The model is used if all tests are positive

o- - The model is used if this testis negative

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