

Internal Inventory Management, Analysis and Improvement for a CPG Company

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ABSTRACT

The sponsor company, a multinational CPG, is under pressure to reduce inventory levels of finished goods and raw and pack materials, while achieving its target sales service level. Currently, it uses a single-echelon inventory management approach. This prevents the company from achieving cross stage inventory improvements. For that reason, in our research, we analyze the benefits of pooling the variance from the customer facing demand while setting the inventory levels at the raw materials stage. We developed a model built on the sponsor company's model, adding the link between the final demand variability with the stock policies for raw and pack materials. Through a simulation on a sample of finished goods and their raw materials, we found that that accounting for the final demand variability in both stages leads to a significant reduction of inventory levels. Our proposed inventory management procedures and guidelines help the sponsor company to reduce the inventory capital investment, without affecting its service level.

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List of Acronyms

CPG: Consumer Packaged Goods

DC: Distribution Center

FG: Finished Goods

Model:

- Proposed Model: The model that is developed in this research project
- Used Model: The model that is developed and currently used by the sponsor company

MPS: Master Production Schedule

MRP: Materials Requirements Planning

RPM: Raw and Pack Materials

SKU: Stock Keeping Unit

SD_{fe} : Standard deviation of forecast error

SD_d : Direct standard deviation of demand

1. Introduction

For consumer-packaged goods (CPG) companies there is a constant challenge for reducing the inventory costs and achieving targeted service levels. In this case, the sponsor company is a CPG leader enterprise with more than 400 brands and presence in 190 countries. Mexico is a key location for the company; it has five production plants and one distribution center (DC). It has several categories such as foods, home care, and personal care, and each category is composed of families such as hair and skin care. Its customers are large retail chains like supermarkets and drugstores.

This project focuses on inventory management for finished goods (FG) products and its raw and pack materials (RPM) for the hair care family in Mexico. The production plant for the Hair category is located in an industrial zone, 150 km from the finished goods DC in Mexico City.

Currently, the sponsor company uses a single-echelon inventory management approach. This prevents the company from achieving cross stage inventory improvements. For that reason, in our research, we analyze the benefits of pooling the variance from the customer facing demand while setting the inventory levels at the raw materials stage.

Initially this section explains the importance of inventory management and the motivation for the company. Then, it describes the current replenishment strategy, the flow of information, and practices. Finally, it identifies an opportunity to improve the current inventory management, by lowering inventory levels while maintaining service levels.

1.1 Motivation

The sponsor company, like all CPG companies today, is under tremendous pressure to lower the inventory costs, whilst improving or maintaining service and flexibility. This is a big challenge

when the company optimizes inventory in multiple stages independently from each other. The company has two inventory stages, one for finished goods at the DC and another one for raw and pack materials at the manufacturing warehouse. Each inventory keeping stage has an independent strategy to achieve the required service while reducing the inventory cost, with an intracompany scope. In this scope, each operation within each stage of the supply chain attempts to minimize its own cost (Chopra, 2013). This is called single-echelon inventory management, which will be described in the literature review chapter. Each stage holds a decoupling safety stock, which allows the actions of a stage to be isolated from the other stages.

In this project, we analyze strategies to align the overall inventory levels across the supply chain stages to maintain or improve the FGs service levels and lower inventory costs. The proposed models will suggest the adequate levels of RPM and FGs in any stage of the supply chain by balancing inventories across the stages. This will be done by taking insights from the risk pooling techniques used in multi-echelon inventory management, which reduce the overall inventory levels. For the purposes of this project, it will be limited to the two internal stages of the company (RPMs and FGs), but future research could extend it to suppliers' and customers' inventories.

With the current practices that optimize the safety stock levels at each stage, the company has a push model, which means that the inventory of finished goods is used to buffer against the customer facing demand. The inventory of raw and pack materials is used to buffer against the variations of the master production schedule (MPS). The drawback of the current practices is that these local inventory policies will not provide the best global (across stages) inventory policies because it does not pool inventory across those stages (Willems, 2016).

Finally, we propose in this research project to link the finished goods forecast errors or demand variability not only with the finished goods inventory, but also with the raw and pack materials

inventory management based on classifications of the stock keeping units (SKUs). This will result in greater flexibility and responsiveness to changes in customer facing demand, while a global inventory strategy will be defined for the company to achieve the desired service level.

1.2 Overview of the current Inventory Management Policies and Operations

The sponsor company "Company CPG," is a consumer packaged goods manufacturer and distributor, offering products through its various brands in food and personal care sectors. In this case, there are two inventory keeping stages. Finished goods (FG) inventory stage at CPG's distribution center (DC), and raw and pack materials (RPM) at the CPG's production plant. The current levels of safety stocks are set separately for each stage, see Figure 1.

Initially, the Demand Planning team creates the stock policy for FGs. The planner calculates the standard deviation of the historical forecast compared to the demand history (actual sales). With the future FGs forecasted and its historical standard deviation, the FGs stock policy is calculated, specifying the safety stocks and maximum levels of inventories. Then, the Supply Planning team creates the Master Production Schedule with the current FGs inventory levels, the forecasted demand and the stock policies. The MPS has one week of frozen period.

Then, the material planners calculate the stock policy and safety stocks for RPM materials. The procedure to calculate the RPM stock policies differ across the different production plants. For this case, the RPM standard deviation is calculated from the consumption production history in a specific plant. In other regions, the inputs for the estimation of the Safety Stocks are the Mean Absolute Deviation (MAD) of the historic MPS compared to the actual consumptions. Finally, the planners create the MRP with the current RPM inventories, the MPS, and the RPM stock policies.

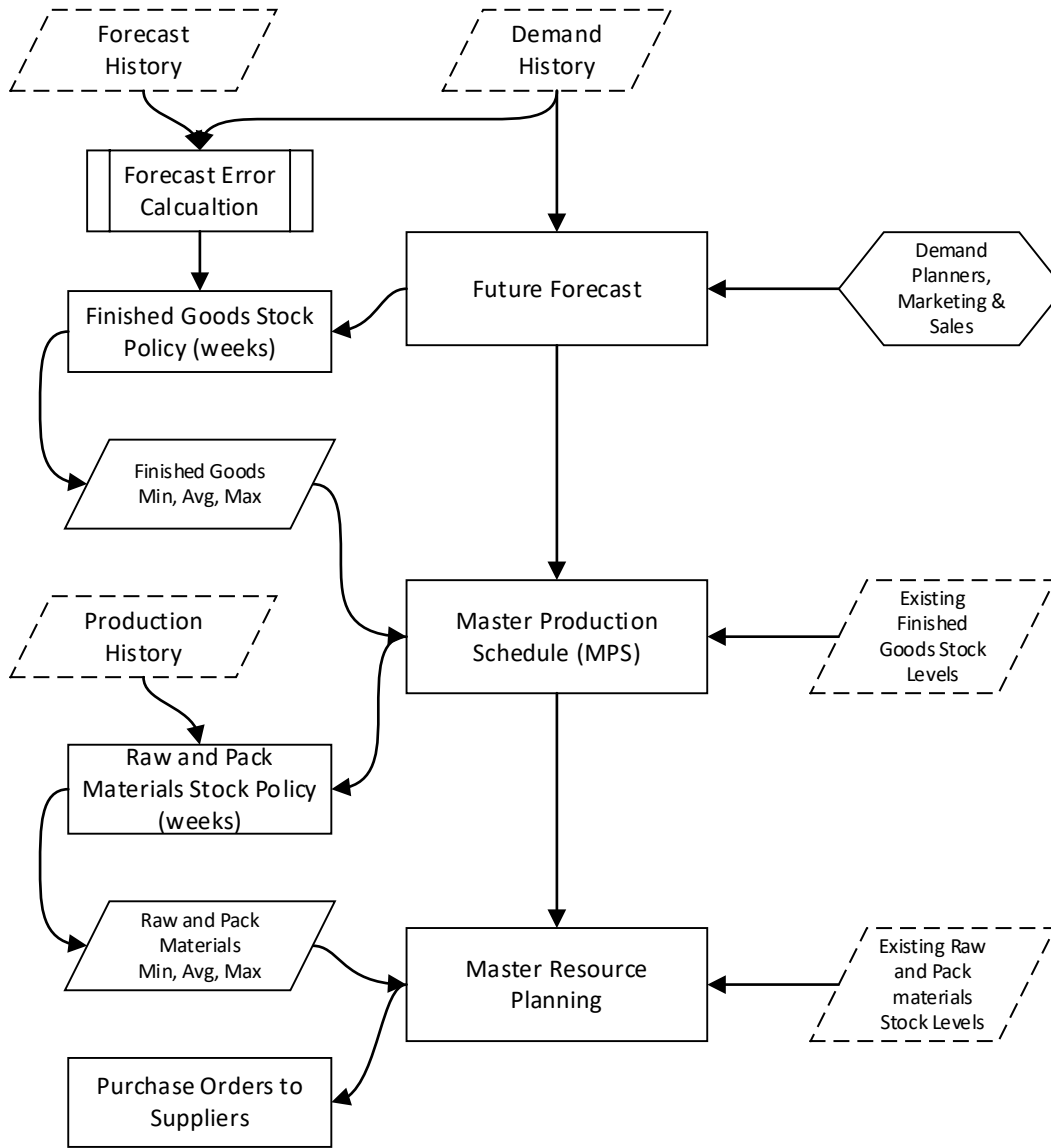


Figure 1. Current Process for setting replenishment policies for finished goods and raw & pack materials.

1.3 Problem Statement

There is a high degree of variation in Company CPG's supply chain both upstream and downstream. In the customer facing side (downstream), complex demand patterns and seasonality trends in the market drive these variations. International sourcing of raw and pack materials with

long lead times, variable capacity and uncertain responsiveness, add complexity and variation to the upstream stage.

The sponsoring company produces forecasts for FG at the end of each year, for the following year, and then the forecasts are revised and updated every two weeks. The role of the forecasts is to capture a large portion of the variability that appears in demand and incorporate seasonality trends. Therefore, the accuracy, or otherwise the error of the forecasts, is what determines the level of the safety stocks for the products. The MPS has a lot of flexibility, based on the real FGs' sales, inventories, and, updated forecast, it is adjusted every week, leaving only one week as a frozen period. To buffer against these errors and flexibility, safety stock is kept for Finished Goods and Raw/Pack materials.

In the next sections, the safety stock will be calculated to ensure a certain service level that the company wants to promise to its customers. We examine various inventory management strategies both for Raw and Pack Materials (RPM) and Finished Goods (FG) for a category of Company CPG. The aim of this research project is to analyze first the current inventory management policies, and then propose improvements or new policies. The main approach is to include the variance of demand that the further downstream FG stage faces when setting the safety stock for RPM stage. This expands the visibility over both stages instead of locally optimize the safety stocks at each stage. The focus will be on internal company operations and policies.

2. Literature Review

In this section, we lay out the key research that has been done in the field of inventory management relevant to this research project. Two main concepts were discussed previously, the single echelon approach and risk pooling from multi echelon approach. In addition, the discussion includes the segmentation methods that are used to narrow down the scope of the project, and the method for the evaluation of the results.

2.1 Single Echelon Inventory Management

The Single Echelon Inventory Management approach sets the safety stock levels for the FG to buffer against production lead time and customer facing demand, while the safety stock levels for RPMs are set to buffer against the variation of Master Production Schedule and lead time from suppliers.

Single echelon inventory optimization models aim to set a replenishment policy locally and independently for each stock keeping level (echelon), based on each echelon's cost and service level considerations. Forecasted versus actual demand errors from the next stocking level downstream, and lead time from the previous level upstream are the most important parameters for these models. Main parameters for the upstream stage are supplier availability, transportation, and production lead times (Silver et al., 1998). Because only one stage's replenishment policy is optimized according to the before mentioned parameters, without regard to its interdependency to other further downstream and upstream echelons, the supply chain can carry excess inventory between upstream echelons, but still have stock outs to the customers (Evant, 2003).

The mathematical approaches and tradeoff curves and relevant costs for single-echelon inventory levels are straightforward. This provides the benefit that for each stage, when a service level factor is set, the safety stock inventory levels are implied and vice versa. The relevant costs are also calculated as a continuous function, and this is a very important property that will be used when setting the safety stocks based on a desired service level metric.

2.2 Multi Echelon Inventory Management

Multi-echelon inventory management considers all the inventory keeping stages to evaluate in a holistic way the total relevant cost and service level provided to the customer. A key assumption in this approach is that due to the interdependency of all the stages or echelons, a stock out at a particular stage can also impact stocks or service level at other stages.

For the multi-echelon approach, dynamic programming models have been developed by Graves & Willems (2000) for tree systems. These models are based on a bounded demand function, and are better deployed for relatively level and stable demand patterns. Also, these models optimize the safety stock allocation and levels based on the added value for the product at each stage. For this project, because we examine only two stages, these models cannot be used. This is because these models are designed for supply chains that are push-pull hybrids, with more than four stages – for example, if the company had ownership of its suppliers’ or customers’ safety stock.

In this project, we will use a very important property of multi-echelon models, “inventory pooling”. This allows for the raw and pack materials stage to have visibility not only to the production stage, but also to the customer facing demand. The use of this property will be explained in detail in the Methodology chapter.

2.3 Segmentation

Finished goods and raw and pack materials have different behaviors across the supply chains, so analyzing and managing all the products the same way would not be efficient. On the other hand, having a specific supply chain design for each product would be extremely complex. Segmentation helps to combine products into groups that share similar features aiming to simplify inventory management and operate more efficiently and/or effectively. (Caplice, 2015).

ABC classification is used in this project, based on the economic value of the products. Although it is a very good method for addressing inventory SKU complexity, it does not consider the variation of demand for these products. For products that are classified as “C”, it is important to find the production pattern, as they are likely produced with lower frequency. Then the variability of the demand will be analyzed to determine the inventory strategy.

2.4 Models Formulation and Evaluation

Literature suggests the use of different data sets when formulating and evaluating different models to avoid overfitting and biased performance of the model in the future. The data must be partitioned in smaller subsets. One subset, the training set, will be used for the formulation of the models. The other subset, the validation set, will be used to evaluate the performance of these models. Consequently, because the objective is to generate models that will have good predictive power on future data, the training set must be independent from the validation set.

3. Methodology

In this section, we describe the current inventory model as well as the development of the proposed inventory model. We analyze in detail the model we developed to calculate the two-echelon stock policies that minimizes cost. The stages are: 1) finished goods distribution center and 2) raw and pack materials warehouse at the production. First, we define the scope, mentioning the possible alternatives for future research. Then explain the process for the data collection and analysis. Next, we show the segmentation method used to cluster and reduce the number of items. Finally, we describe the model development process.

3.1 Scope

The sponsor company is concerned with finding the optimal inventory distribution within their supply chain for their manufacturing process. The project is limited to the inventory strategy within the internal stages of the company. To evaluate the differences between the two models without being affected by particular specifications of the sponsored company, the project does not consider warehouse or production capacity as this creates high complexity in the model.

3.2 Data Collection

First, we gathered and cleaned all the data and information needed for the model. Then, using segmentation methods, the finished goods and raw and pack materials were clustered. Finally, using the selected SKUs, we analyzed both methodologies, the current and the proposed one.

One year of forecasted demand and actual weekly sales of all 250 FG SKUs were extracted from the company's system. Because of the high level of innovations and obsolete items, many SKUs did not have representative information to analyze. We came to a final number of 82 FG SKUs

with complete information and history to be analyzed and included in the model. The relevant information for each SKU needed for the analysis was: one-year history of forecast and real sales, their bill of materials, batch order quantity and price. To simplify the model, the desired service level, overall reliability of production, periods between review, transit time and production frozen period were set equally for all FG SKUs.

The bill of materials (BOM) with consumption quantity per each of the 82 FG SKUs was also extracted from the system. The attributes of each raw and pack material were shared by the MRP planners. The relevant attributes for RPM are: lead time, processing and quality time, price, minimum order quantity and rounding values. The current model calculates the standard deviation from the historical consumption. As an alternative approach, we took the real standard deviation of the materials as an input to the model.

The company also shared their current models, to calculate their stock policies at each stage and to build the MPS.

3.3 Segmentation

The first step of this project is the segmentation of the finished goods and raw materials. In this step, the finished goods will be segmented with a multi-criteria classification according to their revenue contribution and demand variability; this is in order to narrow the scope of the project to the most important ones. The first criterion will be ABC classification according to annual purchasing value percentage contribution versus the percentage of finished goods SKUs. This is a widely used classification method that can provide a first rough estimate of the importance of each SKU. However, this method overlooks other significant attributes of the SKUs such as how predictable their demand pattern is. This can be measured by their forecasted accuracy, with the calculation of the variance of their forecasting error (Figure 2).

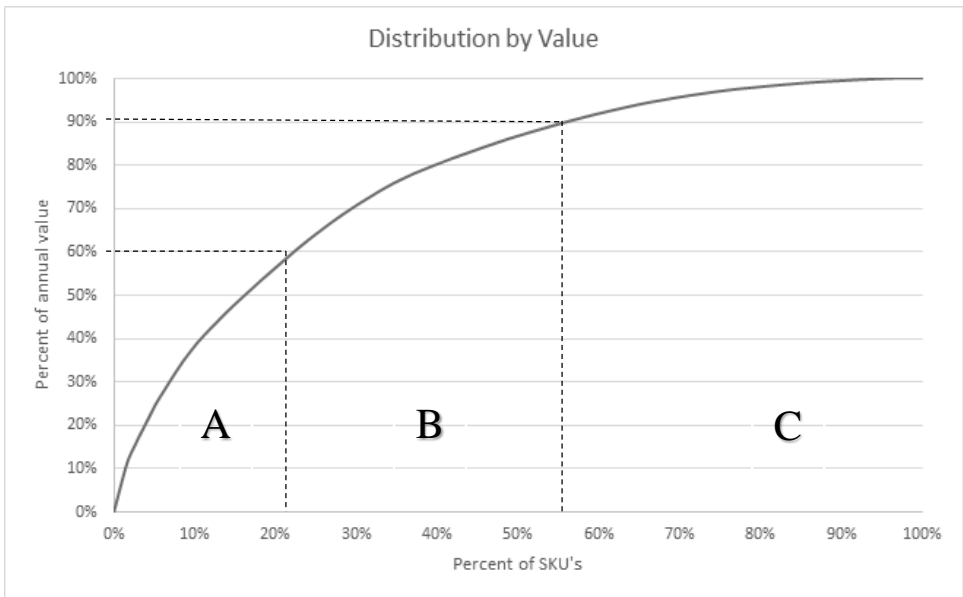


Figure 2. ABC Analysis, Percentage of SKUs and their Percentage standard-price Value

The second criteria to select SKUs for our analysis is the demand variability (measured as the coefficient of variation of its forecast error) versus the economic value for each SKU (Figure 3). This is an indication for setting the target cycle service level for each SKU. For example, high variable - high value SKUs should have higher target cycle service level.



Figure 3. Segmentation: Economic Value versus Variability. Emphasis to be given on the upper right cycle, with A class and high variable FGs. Adopted from: MITx_CTL.SC1x, Week 1-Lesson 2.

Finally, through the BOM of each finished good, raw and pack materials were segmented by type (corrugated, bottle, cap, label, other pack, fragrance and other raw materials). Each type then was segmented according to the criticality of the material. The framework used for this segmentation for raw materials was the Value and Risk Mapping Matrix, (Caplice et al., 2015). For example, the labels of the packaging are of low value but have high impact on the production of finished good because they are unique to each material. Also a raw material that is common for many FGs is of high impact. If this one material stock out, it will affect many FGs. Therefore, higher cycle service level (and higher safety stock) is required for a high impact raw material.

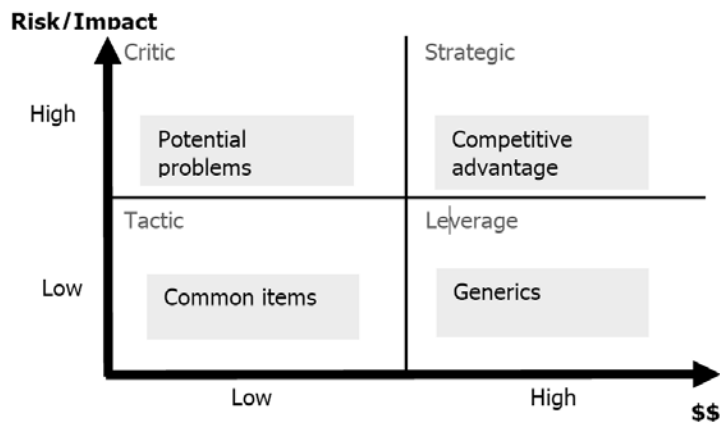


Figure 4. Example of Value and Risk Mapping Matrix, as adopted from MITx_CTL.SC2x, Key Concept Document 2016, version 2, for illustration purposes only.

3.4 Calculation of Standard Deviation of Forecast Errors

In the models that the sponsor company shared with us, the calculation of the standard deviation of the forecast errors versus the actual demand is an approximation with the mean absolute deviation of the forecast (MAD). Specifically, the standard deviation of forecast error (SD_{fe}) is calculated as 1.25 times the MAD. This is a good approximation for when the forecasting errors follow a normal distribution. However, when approximating the normal distribution there can be

differences in the standard deviation. The standard deviation of forecasting errors can also be calculated directly from the errors of the actual customer facing demand versus the forecasted. This approach will more accurately capture the SD_{fe} compared to the approximation method. For this project, both approaches are evaluated.

3.5 Model Development

In this section, we describe the development of the proposed model and the main differences to the existing model. As discussed in the previous sections, we will create and analyze a multi stage inventory management policy. It will determine the adequate levels of safety stocks at each stage, FGs at the DC, and RPM at the CPG's Production Plant. These levels will be calculated in order to satisfy the same expected service level for FGs as the current model. The production capacity and warehousing capacity are ignored for both models (current and proposed). The aim of the analysis is to evaluate the benefits of the model in terms of value of inventory and final service level provided.

Figure 5 shows the proposed process for setting replenishment policies for finished goods and raw and pack materials. The key input for the FGs stock policy is the demand and standard deviation of the FGs. In the proposed model, it can be calculated in two different ways. Then the model selects the most appropriate standard deviation for each FG. The two techniques to calculate the standard deviation are the forecast error (described later which section) and the variance of demand versus the average demand. Then, the model decides which of the two lowers the inventory without risking the service of the FG. In general, FGs with high variability (top right section of Figure 3) will use the demand error, and stable FGs (bottom right section of Figure 3) will use the variation over the mean. The output data of the stock policy are: the safety stock (or safety time) as well as the minimum, average and maximum inventory levels for each FG.

In parallel with building the stock policies, the demand planning team takes the historic demand and the insights of demand planning, marketing, and sales to generate (update) the forecast every two weeks. The forecast is then used again in the stock policy to calculate the safety stocks in terms of future forecasted demand safety time. Each week the MPS will calculate the productions taking as inputs the on-hand inventory, the stock policy and the future forecast.

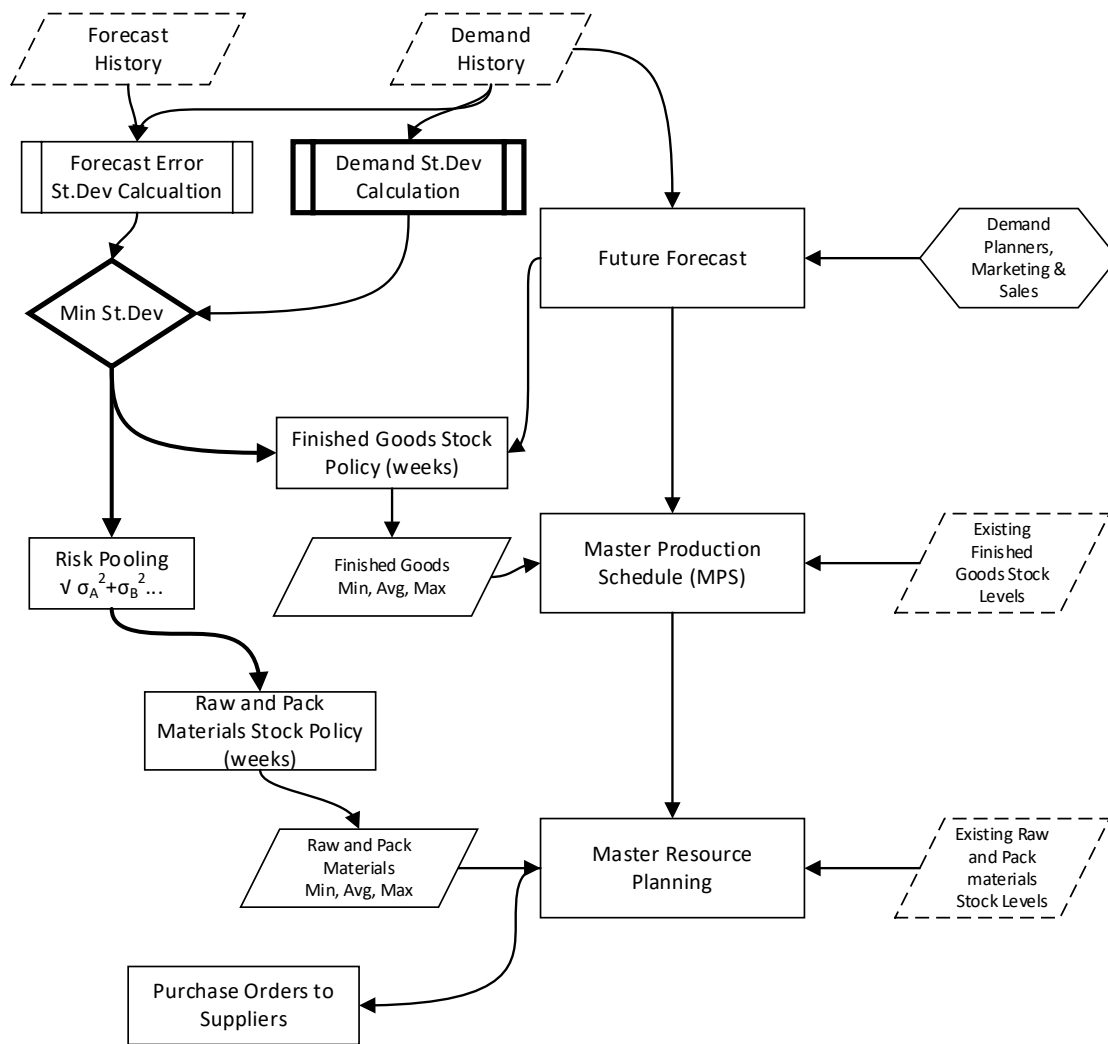


Figure 5. Proposed Process for setting replenishment policies for finished goods and raw & pack materials. To compute the RPMs stock policy, instead of calculating the standard deviation from the historic consumption, the model relates to the real variance of demand. The proposed model pools the

selected FGs standard deviation from the dependent finished good to each material to calculate the aggregated standard deviation. The calculated standard deviation, the MPS and the current inventory levels for RPM are considered to develop the MRP.

3.5.1 Stage 1: Finished Goods Stock Policy

The two data inputs needed to calculate the standard deviation are the historic forecasts and the historic demand. Currently, the forecast is shared (with minor changes) every week and updated every two weeks. The sponsor company calculates the standard deviation of the forecast errors using the mean absolute deviation of the forecast; the details of the calculation are explained in section 3.4. Then, the standard deviation is adjusted to compensate for bias. If the forecast is negatively biased, the standard deviation is increased and vice versa. In the proposed model, it is added also the standard deviation of the mean historic demand is also calculated.

FGs stock policy calculation

The FGs stock policy will determine the safety stock or safety time, and the minimum, average, and maximum inventory levels for each FG. In the current model, the inputs to calculate the stock policy for each FG are: service level, production lot size, lead time, the future average demand per week and standard deviation of forecast error. To compare both models, all the inputs for each FG are the same, except standard deviation and average consumption. The lead time is the summation of the periods between review, frozen period of production, and transit time from plant to DC. To compare both models, we assume the same service level for all SKUs, in reality, the service levels would be adjusted to the segment type of product and customers.

As previously discussed, the difference between the proposed model and the currently used model is the way the standard deviation and average demand are calculated. A decision process is added to the model, when the standard deviation of the forecast error is greater than the standard deviation

of the historical demand, it is decided in the model to use the standard deviation of the historical demand, and vice versa.

Specifically, in the proposed model when the *standard deviation of the forecast error* (SD_{fe}) is lower than the *standard deviation of the historic demand* (SD_d), the safety stock is calculated with the average future forecast as mean demand and its SD_{fe} . Similarly, when the SD_d is lower, the model uses the mean of the historic demand and its SD_d to calculate the safety stock. In general, for high-value (A and B class) SKUs with low variability it is preferable to use the SD of the demand. However, for high-value products with high-variability our model recommends using the SD_{fe} .

MPS calculation

In the current model, the master production schedule (MPS) is used, not only to do the weekly FGs production plan, but also is the connection to the RPM planning. The MPS is calculated with the FGs stock policies. Every week, for each FG, the supply planning team checks the inventory levels and the future forecast. If the inventory level is under the minimum level or will not support another week without production above the inventory level, it generates production. The MPS cannot change the productions of the frozen period, that is why the frozen period is considered in the lead time of the stock policies. For the current model, the MPS is the only connection between the demand and supply planning team. In the proposed model, the supply planning team will look into the demand forecast error and demand variability to calculate their stock policies.

3.5.2 Stage 2: Raw and Pack Materials Stock Policy

Supply planners place Purchase Orders based on the Master Production Schedule forecast that is generated. This poses a significant challenge especially for the RPM quantities to be ordered with long lead times. A planner places a purchase order at period (t) for delivery at period t plus lead

time. After a purchase order is placed this order cannot be changed in most of the cases, so it is important to rely on the safety stocks of the RPMs. For example, if the forecast is revised upwards later in time, there will be a gap that must be covered by safety stock.

Therefore, for the calculation of the forecast error, and its standard deviation, the corresponding forecasts of MPS should be considered. For a RPM with a LT the forecasting error is calculated based on the Actual Consumption in time t and the forecast that was used to place this order ($t+LT$).

Current (MPS and consumption inputs)

In the current setting, after reviewing the current models, the company employs two ways for the calculation RPM safety stocks. One way is to calculate at the standard deviation of the consumption of raw and pack materials and to get the standard deviation that is used to set the safety stock level. The other way is to calculate at the lagging forecasted MPS consumption versus the actual.

Current RPMs safety stock calculation and min max policies

The current calculation of safety stocks is based on the consumption of RPM according to the MPS. First, the mean and standard deviation of each RPM is calculated from the historic actual consumption. Then, the coefficient of variation is calculated by dividing the standard deviation of the consumption of one year over the average consumption per period. Lead time is calculated as the sum of the time from placing an order until it is available for production and it considers, sourcing, producing, transportation, receiving, and quality tests (Figure 6). Finally, the safety stocks are calculated to serve the planned MPS productions using the SD adjusted to their materials' lead time and lot size.

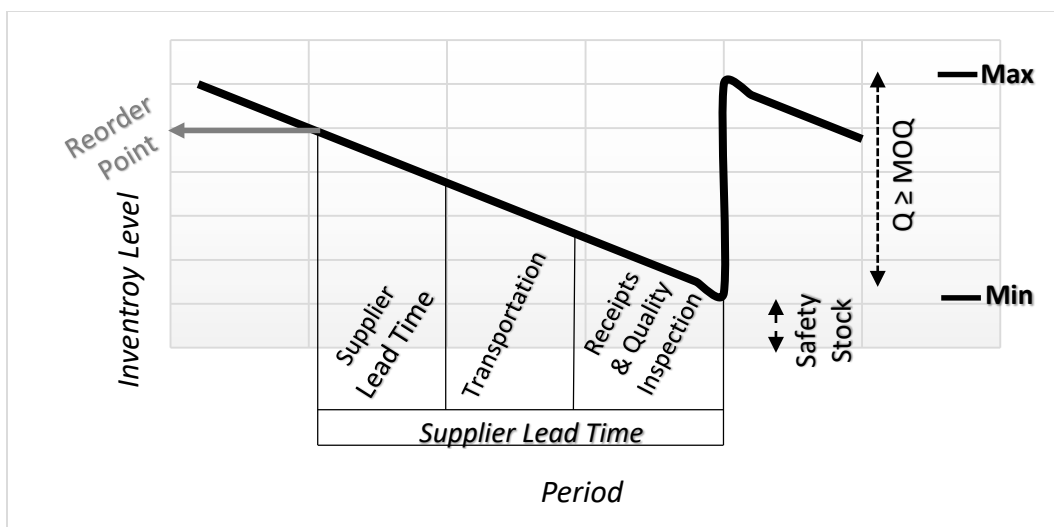


Figure 6. Inventory Replenishment illustration with min-max levels, lead time, and reorder point.

Proposed calculation of RPM safety stock (pooling)

In this project we will calculate the SD of the RPMs based on the lagging (according to the lead time of each RPM) forecasts of their Finished goods. The difference is that instead of summing the consumption of the RPM according to MPS and then calculating the forecast error, we will look directly to the Finished goods consumptions. Based on the variance of the FGs we will pool this variance to each RPM in order to set the corresponding safety stocks. The demand variance of an upstream stage's "RPM-Z" that is consumed by finished goods "FG-A" and "FG-B", is calculated as the pooled variability $\sqrt{VAR_A + VAR_B}$.

4. Results

In this section we proceed to quantitative analysis of the model developed in section 3.5 and compare it to the one that “CPG Company” uses. Specifically, we will examine 82 finished goods corresponding to 373 raw and pack materials in total. Then we will present the results for some SKUs that are representative of each category of the segmentation we initially performed (see section 3.3). To calculate the stock policies and set the initial values of parameters, we used more than one year of data, from 2016 to week 40 of 2017. Finally, the results of the model were evaluated against the sales data of last twelve weeks of 2017.

4.1 Finished Goods Inventory Reduction

Standard deviation is a key component for the calculation of stock levels. The standard deviation we used to set the finished goods’ stock policy is the minimum between:

- i. The standard deviation of the forecast errors of the demand (SD_{fe}).
- ii. The standard deviation of the demand (SD_d).

If the standard deviation that was produced by the forecast errors is bigger than the standard deviation of the demand, this is an indicator that the forecast has low accuracy. Therefore, the SD_d is used.

We exemplify the results (figure 7 and table 1) with two SKUs that have different characteristics (table 1). The coefficient of variation for SKU-1 has a calculated SD_{fe} very close to its SD_d . For this kind of SKUs, there is a marginal difference in inventory levels when using any of the two SD. On the other hand, SKU-2 has much higher SD_{fe} than SD_d because of low forecast accuracy. In this case, the proposed model uses SD_d that results in considerably lower safety stock and

reduction on the future inventory levels, compared to the calculated using SD_{fe} . The result for using SD_d for SKU-2 lowers the average inventory from 5.7 weeks to 1.6 weeks.

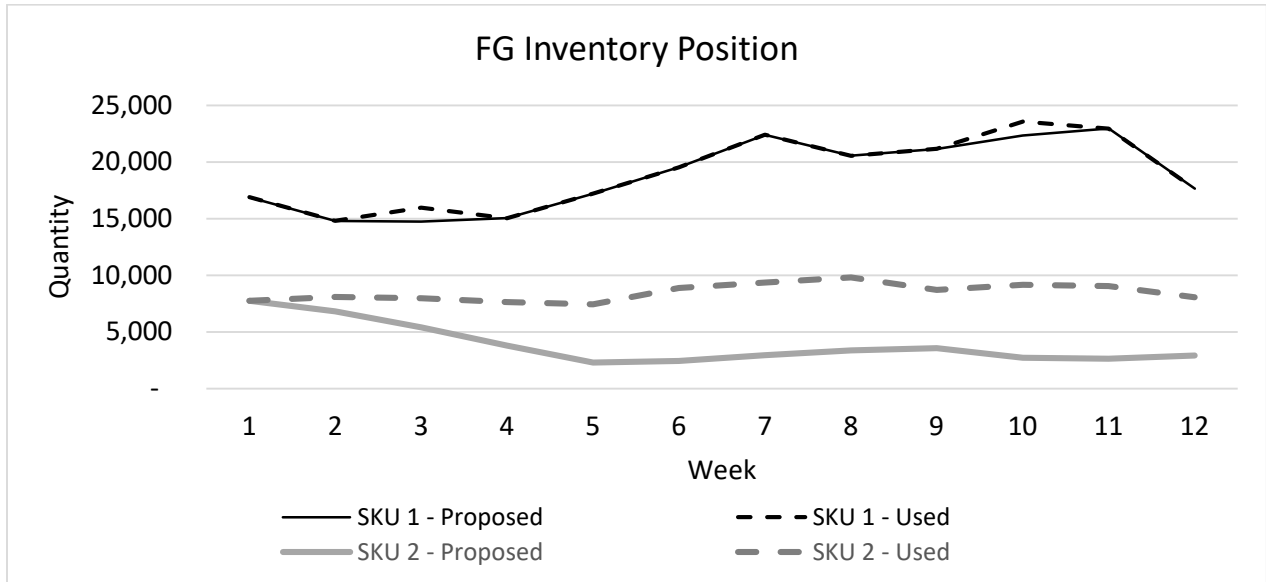


Figure 7. Inventory Positions of two FG SKUs, with the previously used and the proposed model.

Table 1: Example of FG Stock Policies. Comparison between previously used and the proposed model.

Description	Minimum Order Quantity	Coefficient of Variation calculated with the SD_{fe}	Coefficient of Variation calculated with the SD_d	Minimum Inventory in Weeks	Average Inventory in Weeks	Maximum Inventory in Weeks
SKU 1 – Proposed	1,231		101%	3.13	3.27	3.41
SKU 1 – Used		103%		3.19	3.33	3.46
SKU 2 – Proposed	1,285		50%	1.17	1.63	2.09
SKU 2 – Used		173%		5.28	5.74	6.21

Overall, the proposed model resulted in an eight percent reduction in working capital invested in finished goods inventory, from €1.7 to €1.6 million, by maintaining the same cycle service level of 95%. This reduction in inventory is justified from the low forecast accuracy because safety stock is a direct function of either the SD_{fe} or SD_d .

4.2 Raw and Pack Materials Inventory Reduction

In this section we examine the availability of raw and pack materials (RPM). It is very significant to have highly available the critical RPMs that impact several finished goods. Next, we calculate the raw and pack materials stock levels by pooling the standard deviation of demand from their finished goods (section 3.5.2 provides a detailed explanation). For the RPM (in figure 8), we compare the resulting inventory levels between using the pooled variance from its dependent finished goods, and the variance of the historical actual consumption. Overall, this leads to RPM cycle service level of 97%, and RPM inventory reduction of 13%.

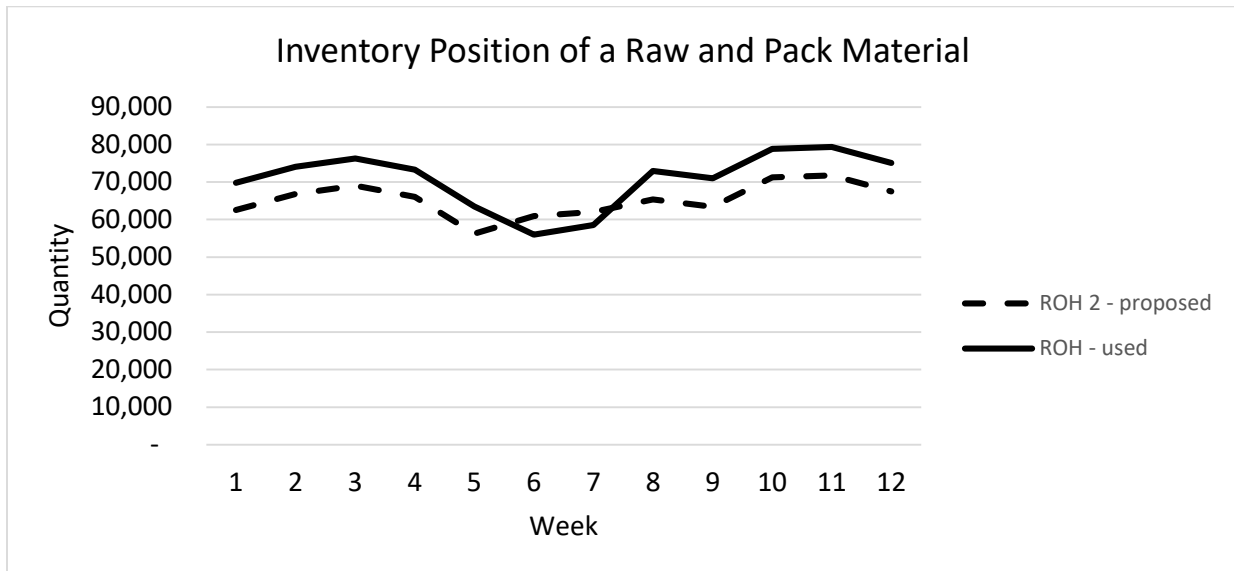


Figure 8. Inventory Position of a critical Raw Material (used in 49 out of 82 finished goods), with high value (3.4% of weekly average RPM value).

4.3 Total Reductions

After building the stock policies using the currently used model and the proposed model, we calculated a total inventory reduction of 11%. For finished goods, by adding the decision variable between the SD_{fe} and SD_d to calculate the safety stock, as illustrated in section 4.1, there is a reduction of 8% in inventory capital investment. Then, for raw and pack materials, by pooling the

variance from their dependent finished goods, as described in section 4.2, there is a reduction of 13% in inventory value (table 2).

Table 2. Total inventory value comparison. Currently used versus proposed model.

<i>In thousands</i>	CPG's Model	Proposed Model	Difference	Difference%
Raw and Pack Materials	\$2,549	\$2,230	\$321	13%
Finished Goods	\$1,735	\$1,599	\$136	8%
<i>Total</i>	<i>\$4,284</i>	<i>\$3,827</i>	<i>\$457</i>	<i>11%</i>

5. Discussion

This research project started with the question to explore whether “CPG Company” can lower its inventories and simultaneously maintain the same service levels that it promises to its customers. Our research concludes that this is possible when adding a decision variable for finished goods and pooling the variability of FGs to the raw and pack materials' stock policy.

First, for the finished goods inventory keeping stage, we found that by taking into consideration either the customer facing variability of demand, or the variability of the forecasting errors, this results in reduction of weekly average inventory capital that “CPG Company” commits to finished goods whilst maintaining the service level. For each finished good, we selected the minimum between these variabilities.

Second, for raw and pack materials, we found that by taking into consideration the variability from their dependent finished goods, instead of the variability of the historic actual consumptions, leads to thirteen percent capital investment reduction to raw and pack materials inventory keeping stage. Connecting the inventory decisions of the multiple stages of any supply chain closer to the customers' demand allows lowering the overall variability of the components.

Third, by improving the forecast accuracy to have lower variance of forecast errors than the variance of demand, will lead to significantly lower inventory capital investments. We recommend further research to develop demand forecasting models that will leverage customer data and will have better predicting power than those currently used. Finally, collaboration with customers for the generation of forecasts is critical to achieve better forecast accuracy.

This project shows how the “Company CPG” can calculate the inventory policies for FGs and RPMs differently, through materials segmentation and visibility of the customer facing demand to

its upstream stages. The results confirmed that the current inventory management practices used by the sponsor company are good when the forecast accuracy is good. Also, the proposed model, in combination with the used model, demonstrated that it can give an overall reduction of 11% in inventory capital investment, while maintaining the same service level.

In this project, we focused on the internal (owned by the sponsor company) inventories. We recommend further research in building inventory policies at suppliers', manufacturers' and customers' stages based on the actual consumer facing demand. The faster the data from the customers' demand become available to each upstream stage, the lower the absolute variability in the supply chain.

Inventory management with visibility closer to the consumption and using different models based on the segmentation of FGs and RPMs are key for CPG companies. Collaboration with the customers and suppliers allows CPGs' companies to get an inventory management advantage.

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