Design for Implementation – Redesigning a Planning Process in a Multinational Company

by

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Abstract

As a consumer-packaged-goods company dealing with multiple suppliers, “Company X” (the company’s real name has been disguised) has a clear need for an accurate raw material forecast. The current planning process has not managed to supply a forecast that will answer Company X’s raw material procurement needs, and so a need for a new process has arisen. Process change initiatives are a task that every company frequently encounters, and creating the right setting for a successful change initiative is critical to determining whether the company will be able to drive the cost savings and remain competitive.

This thesis outlines the process of redesigning the raw material planning process within the company’s regional operations in several developing countries. The new process was designed in an attempt to balance creating a more accurate and more robust forecast with designing an implementable, well-accepted new process that will establish the settings for a successful change initiative.

In the process evaluation section, we examine the new procedure’s potential accuracy improvement, as well as two unique management tools to evaluate the process’ implementation potential and the trade-offs made in designing the process. We evaluate the impact of the finished goods forecast and production error on the overall material plan accuracy.

One common course of action companies typically take in order to decrease material plan variability is to reduce the number of finished goods SKU by aggregating similar SKUs. SKU reduction increases the forecast mean of the individual SKUs and thereby decreases the percent error of the forecast. One interesting conclusion this thesis outlines is that when the production error is not negligible, SKU reduction will only help if the decreased finished goods forecast percent error is above a certain ratio (the square root of the forecast mean). This conclusion suggest that local optimizations of the sub-processes that generate the full material plan will not necessarily optimize the resulting material plan, and that material plan optimization should be done using a comprehensive approach, not as a set of sub-processes optimizations.

While these results, and the methodology for the design and assessment of new process was revealed during my work within company X, the material plan accuracy results are relevant for any material plan process improvement, and the change management methodology discussed is relevant for any company with a need for a smooth and successful implementation of a new process.

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1 Introduction

1.1 Company Overview

Company X is a large CPG enterprise with annual sales near of $20B and more than 50,000 employees. The company has operations in more than 130 countries and is a market leader in more than 80 countries. The company’s regional division has operations in 21 countries, sales in 37 countries and over 18,000 employees. The regional division’s headquarters is located in the US, and the culture within the headquarters is very similar to that of the developing countries. Even though the business language is English, much of the conversations are done in foreign languages. The regional division is divided into four sub-regions regions, and each sub-region has its own VP. In addition to the regional VPs there are three functional VPs – for supply chain, B2B business and human resources. The company’s sites are very much affected by the local culture and present distinguished cultures and business practices.

Recently, the company launched several process improvement projects with the aim of cutting costs and increasing the system’s response time. Those projects were highly successful, received significant support from the company’s directors and achieved satisfactory results. The effort outlined in this thesis to improve the accuracy and visibility of the raw material plan and better support medium and long-term purchasing decisions, is one of those projects.

1.2 Thesis Motivation:

Company X’s regional purchasing team has three major responsibilities: placing raw material orders as necessary, signing periodic long-term agreements with the company’s suppliers, and developing new suppliers when additional capacity is necessary. Purchase orders are placed with a lead-time that ranges from 15 days to 3 months. Supplier agreements are generally negotiated once a year and have a horizon of 12 months. The supplier agreements include expected order quantity for the following year and an ordering quota that will entitle the company to a certain rebate. Those annual agreements are particularly important since most of Company X’s suppliers use them to plan their manufacturing and capacity
requirements. Inaccurate agreements could cause supplier backorders and result in long-term raw material shortages for Company X. In cases where current suppliers do not have the required capacity to answer Company X’s foreseen raw material needs, the purchasing team will either encourage the suppliers to invest in additional capacity or find new suppliers. Adding new capacity or developing new suppliers typically takes six to 24 months.

Throughout 2009 and 2010, Company X encountered significant differences between the estimated and actual consumption of raw materials in its region’s mills. Those differences caused severe losses to the company in the form of lost rebates, purchases of raw materials at sub-optimal prices, excessive inventory and insufficient raw materials that even caused a production halt in several mills in 2009. Figure 1 shows an example for the volatility of the material plan regarding one material in two different regions.

![Figure 1. Over Time Changes in the Material Plan for Raw Material R](image)

Moreover, Company X is currently undergoing a transition from a regional to a global procurement system. Until recently, a regional procurement team verified and checked for consistency the purchase orders made by the local planning teams in the mills and renegotiated annual agreements as the
purchasing forecast changed. With the move to global procurement, the global procurement team will not have the knowledge, the time or the resources to screen purchase orders for errors and minimize rebate losses by contract renegotiation. As a result, with the move to global procurement, an accurate and consistent raw material forecast is even more crucial for the company.

This thesis will focus on the design of a new process that will generate a better raw material plan. It will start with mapping the informational needs of Company X’s regional procurement team and continue with the creation of an implementable process, which will answer those needs. The purpose of the thesis will be to review the design of a new planning process that will generate more accurate results, will achieve maximum stake-holder buy-in, and will be easy to implement uniformly throughout six relevant countries. The new process will standardize the work across the region and will attempt to improve the quality, validity and horizon of the information that is used by the regional and global procurement team.
1.3 Problem Statement

Due to the long lead times in the CPG industry, and Company X’s suppliers’ need to anticipate their raw material purchases, there is a clear need for an accurate and uniform raw material forecast that will supply a longer planning horizon. This thesis will review the process of defining the forecast horizon and granularity required, and redesigning an implementable new process that will generate this new forecast. The thesis will review issues of evaluation of process accuracy, process design for implementation, and change management in a multinational company.

1.4 Thesis Structure

Chapter 1 provides background information for the host organization, outlines the motivation for the thesis, and defines the problem the thesis aims to solve.

Chapter 2 provides an overview of the historic situation in the hosting company.

Chapter 3 describes the process of designing the new planning process, maps the needs of the buying team, criticizes the old process, and reviews the constraints and considerations made in the design of the new process.

Chapter 4 describes the new process proposed.

Chapter 5 conducts gap analysis between the old and the new process.

Chapter 6 evaluates the new process based on its anticipated accuracy and implementability, using both engineering and management models.

Chapter 7 describes the results achieved by the new process in terms of improved accuracy as well as process buy-in.

Chapter 8 contains the conclusions of the analysis, as well as future recommendations and follow-up internship suggestions.
2 The Planning Process

2.1 The General Planning Process

The planning process in each mill generates the production plan, production schedule, and the material plan.

**Production Plan**: high-level plan, dictates which finished goods will be manufactured in each time period, typically has 2-6 month horizon

**Production Schedule**: shift-by-shift description of mill schedule, which machine will manufacture which product at what time. Typically has 15-60 day horizon.

**Material Plan**: the materials that will be consumed according to the production plan, same horizon as the production plan.

![Diagram of the planning process at a typical mill](image)

Figure 2. The Stages of the Planning Process at a Typical Mill
The planning process, outlined in figure 2, is a monthly process and has several stages:

1. **S&OP – Sales and Operations.** A team of sales staff, marketing staff, and planners generates a finished good forecast for the local region. The demand analyst creates a forecast baseline based on historical sales, which will be reviewed and adjusted by sales and marketing teams. Typically a brand-level forecast is created and later disaggregated to the stock-keeping unit (SKU) level. This forecast is later divided and given to specific mills, based on the mill capability and location using a DRP algorithm.

2. **Intercompany Orders** – Some regions also fulfill orders from other regions. The importing region creates a finished goods forecast though its own S&OP process and sends the imported orders to the exporting region.

3. **Production Planning** – The production planner takes the part of the forecast relevant to his mill, current and required inventory levels and machine capacity information, and plans the production for the next months.

4. **Production Scheduling** – The scheduler schedules the work plan for each machine according to the production plan, the machine capacity, and the available inventory of raw material. His schedule aims to minimize set-up costs and production costs, and maintain reasonable levels or raw material inventory.

5. **Manufacturing** – The products are manufactured in the mills according to the production schedule. Specs define the materials needed to produce each finished good. After each batch is manufactured, production confirmation updates the available raw material and finished goods inventories in the system.
6. **Material Planning** – The material planner takes the production plan and the different products’ bill of materials (BOM) and creates the material plan. The material plan is used to make purchase orders for raw materials for the mill.

7. **Product and Technology Development (P&TD)** – Whenever a new product is planned for, the P&TD department is responsible for coordinating with marketing, and issuing the new BOM for the product.

**Long Term Raw Material Forecast**

Recently, in an effort to extend the horizon of the material forecast, the purchasing team has asked each region to generate a long-term material forecast. This forecast has a horizon of 18 months, generated solely by the material planner and predicts the future raw material needs of the mill. Even though not enough time has passed to measure the accuracy of the long-term material plan, it has proved to be inconsistent with financial forecasts, anticipated plant capacities, and sales and it did not account for new BOM of new products or changes in existing BOMs. In fact, as seen in Figure 3, many long-term material forecasts have been generated by copying the last month of the short-term forecast.

![Figure 3. 18-month Material Plan in a Certain Country – Only the First 6 months Contain Meaningful Data](image-url)
2.1.1 The Planning Process by Region

The planning process is similar across the region. However, there are several differences between the regions that also affect the accuracy of the resulting material plan. The company has a dedicated system to input and calculate the production plan and the material plan, and a master data system that holds all the information of the forecasts, BOMs, and machine capacities. A region can only use the company’s dedicated system to plan its production if the master data is updated for the materials and machines used in that region.

2.1.1.1 Sub-Region One

The planning process is done with a horizon of 6 months. The material planning process is done using Company X’s internal information system.

2.1.1.2 Sub-Region Two

The planning is done with a two-month horizon. The material planning is done using Excel modules created by the local material planner and much of the production rates and BOM information on the company’s database is incorrect or obsolete. It is not currently possible to run accurate material planning on the company’s dedicated system.

2.1.1.3 Sub-Region Three

The finished goods forecast is generated in two levels, strategic and tactical. The tactical forecast has a horizon of four months and is used for the planning process, which also has the horizon of four months. The strategic forecast is generated in sub-brand granularity once a quarter. Material planning is done using a locally created Excel module and the BOM and production rates information are not updated in the company’s internal master data.

2.1.1.4 Sub-Region Four
The production plan has a 4-month horizon, but the material plan has a 12-month horizon. The finished goods forecast is generated using the company’s internal system for the first four months but is extrapolated using a spreadsheet for the remaining 8 months. The production plan is created from the first four months, and the material plan is generated by a locally created spreadsheet for the entire 12 months of the forecast.

2.2 The Procurement Process

Company X buys its products locally, regionally, and globally. Local procurement is done by each country’s local team, and it is generally for raw materials that have a very short lead time - 15 to 30 days.

Regional purchasing is done for all the regional division by a regional procurement team located in country one. The local buyer places the order in Company X’s internal system and transfers it to the regional procurement team. The regional buyer chooses a supplier and places the order with it. Thereafter, the local buyer is responsible to track the order until it reaches the local mill. If any changes in future orders are required, or if there are delays in the order, the local buyer will discuss this with the regional purchaser. Global procurement is done similarly to regional.

In addition to placing purchase orders as necessary, the regional procurement team is responsible for negotiating future rates and order frequency and quantity with the regional suppliers. The procurement team is responsible for guaranteeing Company X a constant raw material supply at the best possible rates. The regional buyers generally sign annual supplier agreements that include prices and anticipated orders. Those agreements define a rebate that Company X will be entitled to if its accumulated purchases during the year will reach a certain pre-defined quota.

Due to the volatility in material consumption, annual contracts tend to be re-negotiated throughout the year, as the anticipated orders from a supplier change significantly. Renegotiating contracts mitigates the
unclaimed rebates losses and incentivizes the suppliers to re-plan their production, preventing potential shortages. Despite that, in the past year, Company X experienced significant losses due to lost rebates and purchases of more expensive raw materials when the cheaper suppliers could not deliver the required quantities.
3 Designing a Planning Process

In order to address the needs of the regional procurement team of Company X, our team designed a new planning process. This chapter outlines the work done to design this process.

3.1 Mapping the Needs of the Procurement Team

Several interviews were conducted with 10 members of the procurement team to map and understand their needs. The output of the new process was designed in an effort to best address those needs.

The regional procurement team has three main functions:

1. Placing periodic raw materials orders with a lead time of one to three months
2. Negotiating annual supplier agreements, defining quotas and rebates
3. Identifying the need to develop new suppliers or encourage existing suppliers to increase their capacity when additional capacity is necessary

The raw material forecast is extremely important for all of the functions listed above. The short-term forecast is used to anticipate the raw materials need for each mill and to place periodic orders. When the short-term forecast changes within the lead time, the company incurs losses in the form of excessive inventory (overage), air freight, cross-sourcing or even a halt in production (underage).

For the other two functions, the purchasing team uses a long-term forecast. In the past, this forecast has been obtained from the long-term financial forecast, an estimate done by the buyers, or an estimate done by the material planner.

Several interviews conducted with the procurement teams have generated the following conclusions regarding the process:
Short-term Forecast:

1. Even though the longest lead time for raw materials is three months, the next six months of the material forecast is shared with the suppliers in order to foster better supplier relationships and guarantees material availability. This allows the suppliers to plan their manufacturing accordingly.

2. Since this forecast is generated for placing orders, the required granularity is SKU level.

3. The first three months of the purchase orders are within the lead time, and therefore cannot be modified. The last three months can tolerate certain variations, depending on the type of material and its individual lead time.

4. Orders for each raw material are made or modified about once a month, depending on the frequency of the Material Requirements Planning which changes from sub-region to sub-region.

Long-term Forecast:

1. This forecast is used to anticipate required future supplier capacity. Therefore, the required granularity is defined by the suppliers’ manufacturing processes. Every set of raw materials that is manufactured by the supplier using the same machines could be aggregated, and will be referred to as having the same “technology level”.

2. When a need for new capacity arises, lead time to develop new suppliers is 1-2 years.

3. Supplier agreements are negotiated once a year and renegotiated as necessary.
4. Since the historic forecasts have not been very accurate, Company X's suppliers do not typically rely on the purchasing forecast or the supplier agreements and do not always plan their capacity accordingly.

5. The better the long-term forecast, the easier it is for the buyers to maintain good supplier relationships, obtain better prices and guarantee supply.

3.2 Desired Process Output

With the above considerations in mind, and in an attempt to balance answering the needs of the procurement teams with implementability, our team has defined the following desired material plan for the process:

<table>
<thead>
<tr>
<th>Months 1-6</th>
<th>Months 7-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKU level, One month rolling</td>
<td>Technology level, three months rolling</td>
</tr>
</tbody>
</table>

![Figure 4. The Desired Process Output](image)

The first 6 months of the forecast will be generated at the SKU level, defining exactly which materials should be ordered, and the remaining 12 months will be aggregated to the technology level, and will be used for the suppliers' agreements and long-term capacity planning.

3.3 Issues with the Historical Process

The old process, described in Chapter 2, did not generate the required output as defined in 3.2 and had several additional issues hampering its accuracy.

**Output Issues:**

1. Only a short-term material forecast existed

2. Material forecast horizon from most countries was too short
3. Material forecast horizon inconsistent between the different sub-regions

4. Short-term material forecast was too volatile and inaccurate

**Knowledge Sharing Issues:**

1. Different planning horizon in every country

2. Low visibility of the material forecast – not all plans are stored in one unified system

3. Lack of consistency - different systems used to generate material plan – different spreadsheet were created independently by each region. The company had a dedicated system to store and adjust the plans but not all countries used it

4. Capacity, production rates and BOM information weren’t consistent across regions, most information was held locally and not uploaded to the company’s master data base

5. The information leading to the material plan – the finished goods forecast, the BOMs, the production plan and the plant capacity weren’t visible throughout the organization

6. Historical material plans were not saved in system

**Accuracy Issues**

1. The Excel models that were created locally had calculation issues and human errors

2. BOM and production rates information was not accurate – when comparing the actual consumption with the theoretical one described by the BOMs, clear discrepancies where seen. Figure 8 demonstrate those undesired differences for a certain raw material.
3. Finished goods forecast was not reviewed by marketing and planning team in all countries

Incentives Issues

1. Finished goods forecast KPIs only measured forecast accuracy for a one or two-month horizon

2. Material plan was not stored and compared across time for accuracy, no KPIs or relevant incentives existed

3. Material planners had the incentive to inflate material plan in order to guarantee material availability; they were not held accountable for overage

4. Marketing and sales people were measured mainly on sales, not profits, and therefore had a clear incentive to underestimate the forecast to make sure they reach their sales targets easily
3.4 Constraints and Considerations

When designing the new process, several external considerations had to be taken into account. The goal of the project was to design a process that would improve the resulting forecast, but would also be easy to implement and well-received by the local stakeholders. The main considerations that were taken into account were:

1. Simplicity – preferring simple processes over complicated ones increased local support for the project, decreased the learning curve and allowed our team to support the process implementation with limited resources

2. Benchmarking – a preference for using sub-processes that were already practiced successfully somewhere else in the region was beneficial for several reasons:
   a. Existing knowledge sharing and training resources – the region practicing the sub-process could train and support the other regions with implementation
   b. Guaranteed implementability – processes that are already practiced in other regions are less likely to run into unforeseen implementation problems
   c. Easier buy-in – managers were more inclined to support the processes that were benchmarked

3. Using local management input – all new process elements needed to be approved by the local supply chain managers. For that, their input was taken during the design of the process, and was used as much as possible.

4. Using procurement team input – each revision of the process was reviewed by the regional purchasing team. Both the final output and the process leading to it had to be approved.

5. Minimal disruption – our team preferred processes that were as similar as possible to the old process, or that were easy to transition to. This allowed minimal disruption to the business during the change
6. IT systems – the process had to use IT systems that were either already in place or could be implemented easily with limited time and resources

7. Sustainability – the new process must be easy to sustain and require minimal ongoing support after initial implementation.
4 The New Process

Considering the issues discussed in Chapter 3, our team designed the following process:

![Diagram of the proposed planning process]

The new process will have the following stages:

1. **S&OP**: The S&OP process will generate the following input for the demand planner
   
   - Planning forecast: 6 months horizon, SKU level, updated monthly
   - Financial forecast: additional 12 months, sub-brand level, updated quarterly

![Desired Output from S&OP]

Months 1-6 will be created according to the short term S&OP process.
The baseline for months 7-18 will be created by the demand planner. This baseline will be reviewed quarterly by the marketing, finance, and planning teams of each country to assure consistency with mill capacity, market trends and product pipeline.

2. **Demand Planning:** The demand planner will take the brand level forecast for months 7-18 and disaggregate it based on SKU averages from months 1-6. He will then upload all 18 months of SKU level forecast into the system.

3. **Intercompany Orders:** orders from all other regions will have the same 18 month horizon and SKU granularity and will be delivered to the demand planner.

4. **Production Planning:** The production planner will create production orders for the next 18 months using the finished goods forecast. Only the first six months will be measured for variability.

5. **Production Scheduling:** The production scheduler will schedule 2 months of production planning and confirm raw material availability using the company’s automated system.

6. **Manufacturing:** Product specs, production versions and production rates will be reviewed periodically for consistency with the information on the company’s database.

7. **Material Planning:** Material planner will run MRP for all 18-month horizons using the company’s automated system; he will only place orders as necessary, based on the lead time.

8. **Procurement:** Regional buyers will use the short-term information to place orders and the long-term information to negotiate agreements and develop new suppliers. They will update the system with shipping information and whenever the arrival date for a shipment changes, they will update the change in the system.
5 Gap Analysis and Barriers for New Process Implementation

5.1 Implementation Barriers

The newly designed process differs from the old process in several key aspects and will require the company to complete several prerequisites before moving to the new process. With the old process, most of the planning was done in separate spreadsheets, which were created by the planners and did not connect to the company’s information system. The move toward planning with the company’s information system will require the following:

Data Cleansing: All BOMs, production rates and production versions saved in the company’s master data need to be reviewed and checked for consistency with the specs used for manufacturing. It is also necessary to make sure every product manufactured has a BOM stored in the master database and every machine has its production rates and capacities uploaded. Old BOMs of obsolete materials must be erased and old raw materials which are no longer in use must be removed from the system. Duplicate production versions need to be consolidated. The data stored in the master database must be reviewed periodically and checked for relevance and accuracy.

Cost Analysis: At Company X, cost information is calculated using the BOM and production rates values that are stored in the company’s master database. Changing the BOM and production rates values to match the specs used for production will change the calculated costs of the products. The cost analysis department must review these changes and agree to them. This change is especially challenging since the cost analysis department is not a part of the supply chain business unit.

New Product Development: Whenever new products are developed and orders for these products are made, an internal system code needs to be issued to each new product. Current processes only allow issuing a code for products for which the BOM is finalized, but new product development process only finalizes the BOM four months before the product’s launch date. In order for new products to be planned for using the new process, a tentative BOM must be defined as soon as the product is planned for. Any
new product will be created with a tentative BOM, which will be finalized at least four months before the product’s launch. Changes to the tentative BOM will cause changes in the material plan, but these changes are likely to be minor and within the allowed variability. In most cases, the tentative BOMs are the same as the finalized ones for the critical long lead time raw materials which are the main concern of this project.

**IT Systems:** The company’s information system needs to be readjusted to support the new process. New modules must be created, and new tools must be implemented.

### 5.2 Gap Analysis by Region

The major changes required for the new process implementation in each country were divided into six categories, and the progress of each country was evaluated across all categories:

**Short-term Finished Goods Forecast:** Establish six-month SKU-level forecast based on the S&OP process

**Long-term Forecast:** Establish months 7-18 of the forecast in the brand-subbrand level

**Upload Full Forecast:** Disaggregate months 7-18 to SKU level based on the averages from months 1-6 and upload the full SKU level forecast of months 1-18 to the system

**New Products Policy:** Establish a new product development policy that will enable planning for new product using the new process

**System Data Cleansing:** Update and review all BOM, production rates and production versions in the master data

**Material Planning:** Use the company’s dedicated system to create and store material plans
As seen in the chart, limited process implementation started in CA&C and the Austral region, but most changes were not even planned by June 2010.
6 New Process Evaluation

In this chapter, we will review and assess the new process using both engineering and management tools.

6.1 Accuracy

6.1.1 First Six Months

Define:

\[ F_1^k, \ldots, F_N^k \] The production plan, based on the forecast, for finished goods 1 through \( N \) in month \( k \)

\[ B_{nm}^1, \ldots, B_{nm}^k \] The effective BOMs (considering production error) of material \( m \) for finished goods 1 through \( N \) in month \( k \)

\[ M_1^k, \ldots, M_M^k \] The forecast for raw material 1 through \( M \) for month \( k \)

For every material \( m \) and month \( k \) it holds that:

\[ [1] \quad M_m^k = \sum_{n=1}^{N} F_n^k \times B_{nm}^k \]

In first approximation, the error (estimated by the standard deviation) in the material forecast can be defined as:

\[ [2] \quad \Delta M_m^k = \sum_{n=1}^{N} (\Delta F_n^k \times E[B_{nm}^k] + E[F_n^k] \times \Delta B_{nm}^k) \]

For the purposes of the accuracy evaluation, we will assume that the BOM inaccuracy \( \Delta B_{nm}^k \) is a random percentage of \( E[B_{nm}^k] \), and is not correlated to the \( E[F_n^k] \). Therefore, we will substitute \( \Delta B_{nm}^k \) with \( v \times Y_n \times E[B_{nm}^k] \) when \( Y_n \) is a random variable with mean 0 and STD 1 and \( v \) is the effective BOM’s Mean Average Percent Error (MAPE).
For the finished goods forecast, we will assume a constant variance $u^2$ for each unit of finished goods forecast (the units are defined arbitrarily, and the coefficient $d^2$ which we will introduce later will calibrate for the unit choice). Under that assumption, I will first show that $\Delta F_n^k$ linearly depends on $\sqrt{E[F_n^k]}$.

The total variance $V[F_n^k]$ can be defined as:

$$V[F_n^k] = \sum_{n=1}^{F_n^k} u = F_n^k \times u^2$$

And so, the total STD of demand will be $\sqrt{E[F_n^k]} \times u$. This result also lies in some agreement with observations from the mills, existing KPIs and interviews conducted with the planners and demand analysts. Figure 10 shows the ratio between the total demand and the demand variability for a typical product.
We will substitute \( u^2 \) with \( d^2 \cdot \alpha_k^2 \), where \( d^2 \) is a coefficient that calibrates the units for \( \sqrt{E[F_n^k]} \), and \( \alpha_k \) is the monthly variability coefficient. Based on past observation and an estimate of the range of the forecast variability, \( d \) should be defined in the following way:

\[ \forall n \text{ such that } E[F_n^k] \text{ is at 10th percentile of the } E[F_n^k] \text{ distribution,} \]

\[ \sqrt{E[F_n^k]} \cdot d = E[F_n^k] \rightarrow d = \sqrt{E[F_n^k]} \]

We have defined \( d \) in such a way that for every product that has a mean demand quantity that is at the bottom 10th percentile of the products' demand distribution, the MAPE of the demand for that product will equal to exactly \( \alpha_k \).

As for \( \alpha_k^2 \), in order to fit observed forecast values, we will define \( \alpha_k^2 \) for every month \( k \) as following:

![Figure 10. \( \alpha_k^2 \) values for each different \( k \)](image)

After six months, for \( k \geq 6 \), \( \alpha_k^2 \) will remain constant at 50%.

Following the listed assumptions, the inaccuracy in material requirements can be modeled by:
\[ \Delta M^k_m = \sum_{n=1}^{N} \left( \alpha_k d X_n \sqrt{E[F_n^k]E[B_{nm}^k]} + \nu Y_n E[B_{nm}^k] E[F_n^k] \right) = \]
\[ \alpha_k d \sum_{n=1}^{N} \left( X_n \sqrt{E[F_n^k]E[B_{nm}^k]} \right) + \nu \sum_{n=1}^{N} \left( Y_n E[B_{nm}^k] E[F_n^k] \right) \]

When \( X_n \) and \( Y_n \) are random variables with mean 0 and variance of 1. We will further assume that all \( E[F_n^k] \) and \( E[B_{nm}^k] \) are independent for every \( k, m, n \) and so \( X_n \) and \( Y_n \) will also be independent. This assumption does not hold on reality, as the forecasts for the different months, the BOM errors, and the different products do depend on one another. However, past observations in the company suggest that the inherent random forecast and BOM error is significantly larger than the cross-months and cross-products correlations. Therefore, we can reasonably assume a lack of correlation without affecting the validity of our model.

Under these conditions, we look at equation [3] as two sums of many independent random variables with different variances. Applying random variables’ algebra [3] we receive:

\[ E[\Delta M^k_m] = m_x \alpha_k \sum_{n=1}^{N} \left( \sqrt{E[F_n^k]E[B_{nm}^k]} \right) + m_y d \sum_{n=1}^{N} (E[F_n^k] E[B_{nm}^k]) = 0 \]

And:

\[ V[\Delta M^k_m] = \sum_{n=1}^{N} \left( \left( \alpha_k d \sqrt{E[F_n^k]E[B_{nm}^k]} \right)^2 + \left( \nu E[F_n^k] E[B_{nm}^k] \right)^2 \right) \]

According to the Central Limit Theorem and the Law of Large numbers [1][2] we know \( \frac{\Delta M^k_m}{n} \) will behave approximately like a normal distribution. Since \( n \) is finite, we can also assume that \( \Delta M^k_m \) behaves approximately like a normal distribution.

The new process aims to minimize the variance \( V[\Delta M^k_m] \) of the normal distribution \( \Delta M^k_m \). Looking at equation [5] and assuming a constant total demand for finished goods, we identify three factors that affect the variability of the material plan:
1. The SKU's number – the fewer SKU's there are the smaller $N$ is and the larger each $E[F_{n}^{k}]$ becomes.

2. The BOM variability $v$.

3. The monthly forecast variability coefficient $\alpha_{k}$

**6.1.1.1 Sensitivity analysis**

We will now try to evaluate the material plan error's sensitivity to each of these factors:

**SKU's number:**

Given a constant total demand, we will look at the effect of $x$ reduction in the number of SKU's. The average forecast quantity per SKU will increase by $\frac{1}{1-x}$. For estimation purposes and ease of calculation, we will assume the SKU reduction was done by eliminating a portion $x$ of the SKU's which has a combined forecast quantity that equals to $x$ of the total forecast. To maintain a constant total forecast quantity, each of the remaining SKU's will be increased by the same factor $\frac{1}{1-x}$. Under these assumptions, the new material forecast error will be modeled as:

$$V[\Delta M_{nm}'] = \sum_{n=1}^{N(1-x)} \left( d\alpha_{k} \sqrt{\frac{1}{1-x}} E[F_{n}^{k}]E[B_{nm}^{k}] \right)^{2} + \left( \frac{1}{1-x} vE[F_{n}^{k}]E[B_{nm}^{k}] \right)^{2}$$

The effect of this decrease in SKU's number will change significantly depending on the individual sizes of the $F_{n}^{k}$ and $B_{nm}^{k}$. However, for estimation purposes, we will look at the case were all $F_{n}^{k}$ and $B_{nm}^{k}$ are in the exact same size for every $n$. Under that assumption:
Whereas under the same assumptions, the variability for the material plan prior to the decrease in SKU’s will be

\[ V[\Delta M_m'] = \sum_{n=1}^{N(1-x)} \left( \left( d\alpha_k \sqrt{\frac{1}{1-x}} E[F_n^k] E[B_{nm}^k] \right)^2 + \left( \frac{1}{1-x} \nu E[F_n^k] E[B_{nm}^k] \right)^2 \right) = N(1-x) \left( d\alpha_k \sqrt{\frac{1}{1-x}} E[F_n^k] E[B_{nm}^k] \right)^2 + \left( \frac{1}{1-x} \nu E[F_n^k] E[B_{nm}^k] \right)^2 = E[F_n^k] E[B_{nm}^k]^2 N \left( (d\alpha_k)^2 + \nu E[F_n^k] \right)^2 \]

Looking at the two elements of equation [6] the first element depends on \( d \) and \( \alpha_k \) and the second element depends on \( \sqrt{E[F_n^k]} \) and \( \nu \). If the monthly variability is more significant than the BOM error, the different \( F_n^k \) are very small, then \((d\alpha_k)^2 \gg (\sqrt{E[F_n^k]} \nu)^2\) and

\[ V[\Delta M_m'] = E[F_n^k] E[B_{nm}^k]^2 N \left( (d\alpha_k)^2 + \left( \frac{1}{1-x} \nu \sqrt{E[F_n^k]} \right)^2 \right) \]

\[ \approx E[F_n^k] E[B_{nm}^k]^2 N \left( (d\alpha_k)^2 + \nu \sqrt{E[F_n^k]} \right)^2 = V[\Delta M_m'] \]

And the effect of reducing the SKU number on the material plan is negligible.

However, if the BOM error is larger than the monthly variability, \( E[F_n^k] \) is significantly large, or \((1-x)\) is small, then:

\[ V[\Delta M_m'] = E[F_n^k] E[B_{nm}^k]^2 N \left( (d\alpha_k)^2 + \left( \frac{1}{1-x} \nu \sqrt{E[F_n^k]} \right)^2 \right) \approx \]

\[ \left( \frac{1}{1-x} \right) E[F_n^k] E[B_{nm}^k]^2 N \left( (d\alpha_k)^2 + \nu \sqrt{E[F_n^k]} \right)^2 \left( \frac{1}{1-x} \right) V[\Delta M_m'] \]

So reducing the SKU number by \( x\% \) will increase the material plan variability by \( \frac{1}{1-x} \)
If either element of the equation is not negligible relative to the other, the material plan variability will increase by some $\omega$ such that $1 < \omega < \frac{1}{1-x}$.

This analysis was done using the assumption that the forecast mean is distributed equally across the different SKU’s and that the SKU reduction will be done evenly across all SKU’s. In reality a lower variance increase would be obtained by aggregating only SKU’s with lower-than-average forecast ($E[F_n^k]$) and lower-than-average material use ($E[B_{nm}^k]$). A higher increase in variability would be obtained by aggregating SKU’s with higher-than-average forecast and higher-than-average material use. This is due to the fact that the squaring affect on the forecast quantities will be stronger on large forecast quantities becoming larger than it would on increasing small forecast quantities.

**BOM variability**

Each decrease $y$ in the BOM variability will have the following effect on the material plan:

$$V[\Delta M^k_m] = \sum_{n=1}^{N} \left( (d \alpha_k \sqrt{E[F_n^k]}E[B_{nm}^k])^2 + (vE[F_n^k]E[B_{nm}^k])^2 \right) \rightarrow \sum_{n=1}^{N} \left( (d \alpha_k \sqrt{E[F_n^k]}E[B_{nm}^k])^2 + (1-y)^2(vE[F_n^k]E[B_{nm}^k])^2 \right)$$

The more significant $d \alpha_k \sqrt{E[F_n^k]}E[B_{nm}^k]$ is over $vE[F_n^k]E[B_{nm}^k]$ the less significant the contribution of the BOM accuracy change will be. For very small values of $v$ and $E[F_n^k]$, this contribution could be completely negligible. As $v$ and $F_n^k$ grow larger, the improvement $d \alpha_k \sqrt{E[F_n^k]}E[B_{nm}^k]$ will become more meaningful relative to $vE[F_n^k]E[B_{nm}^k]$ and the material plan improvement generated by will approach $1-y$.

**The monthly variability coefficient $\alpha_k$**

Each decrease $z$ in the monthly variability would have the following affect on the material plan accuracy:
\[ V[\Delta M^k_m] = \sum_{n=1}^{N} \left( \left( d \alpha_k \sqrt{E[F^k_n]E[B^k_{nm}]} \right)^2 + \left( v E[F^k_n]E[B^k_{nm}] \right)^2 \right) - \sum_{n=1}^{N} \left( 1 - z \right)^2 \left( d \alpha_k \sqrt{E[F^k_n]E[B^k_{nm}]} \right)^2 + \left( v E[F^k_n]E[B^k_{nm}] \right)^2 \]

Correspondingly to the BOM accuracy analysis, this result shows that more significant \( v \) and \( E[F^k_n] \)'s are relative to \( \alpha_k \), the larger the effect of the change \( z \) will be to the material plan accuracy. For very small \( \alpha_k \) and large \( E[F^k_n] \), the change in the material plan will be negligible, and for large \( \alpha_k \) and smaller \( v \) and \( E[F^k_n] \) the material plan improvement will approach \( z \).

### 6.1.2 Months six-7 to 1218

For the long term forecast, the forecast is generated in the subbrand level, and then disaggregated to SKU level. For simplicity we will assume that the aggregation and disaggregation generates a forecast error such that the value of \( \alpha_k \) is 50% per SKU for all months 7-18. Before aggregating the forecast to the raw material technology level, the accuracy of the material forecast is modeled exactly like the material plan for the first 6 months:

\[
\Delta M^k_m = 0.5 \sum_{n=1}^{N} \left( X_n \sqrt{E[F^k_n]E[B^k_{nm}]} \right) + v \sum_{n=1}^{N} \left( Y_n E[F^k_n]E[B^k_{nm}] \right)
\]

Aggregating according to technology level, we will sum \( \Delta M^k_m \) for all materials that have the same technology level. Therefore, the aggregated forecast will be:

\[
\sum_{m \in T} \Delta M^k_m
\]

\[
= \sum_{m \in T} \left( \sum_{n=1}^{N} \left( 0.5 d \sqrt{E[F^k_n]E[B^k_{nm}]} \right)^2 + v \sum_{n=1}^{N} \left( Y_n E[F^k_n]E[B^k_{nm}] \right) \right)
\]

\[
= \sum_{n=1, m \in T}^{N} \left( 0.5 d \sqrt{E[F^k_n]E[B^k_{nm}]} + v (Y_n E[F^k_n]E[B^k_{nm}]) \right)
\]
Where $T$ is the set of all $m$'s within a certain technology level. Using random variable algebra, we receive:

$$E\left[\sum_{m \in T} \Delta M^k_m\right] = m_x \alpha_k \sum_{n=1}^{N} \left(\sqrt{E[F^k_n]E[B^k_{nm}]}\right) + m_y d \sum_{n=1,m \in T}^{N} \left(E[F^k_n]E[B^k_{nm}]\right) = 0$$

And:

$$V[\sum_{m \in T} \Delta M^k_m] = \sum_{n=1,m \in T}^{N} \left(0.5d\sqrt{E[F^k_n]E[B^k_{nm}]\right)^2 + (\nu E[F^k_n]E[B^k_{nm}]\right)^2}$$

Assuming a similar size forecasts for all materials in a certain technology group, the effect of aggregating the material forecast by technology level could be evaluated by:

$$V[\sum_{m \in T} \Delta M^k_m] = \frac{0.5|T|N\left(\left(d\sqrt{E[F^k_n]E[B^k_{nm}]\right)^2 + (\nu E[F^k_n]E[B^k_{nm}]\right)^2} = |T|$$

Meaning that the variance of $\sum_{m \in T} \Delta M^k_m$ is $|T|$ times larger than the variance of $\Delta M^k_m$. Therefore, the STD for $\sum_{m \in T} \Delta M^k_m$ will be $\sqrt{|T|}$ larger than the STD of $\Delta M^k_m$. Therefore, $\sum_{m \in T} \Delta M^k_m$ has an MAPE that is $\sqrt{|T|}$ times smaller than that of $\Delta M^k_m$. Better error reduction will be obtained by aggregating multiple materials with small material forecasts, and lower error reductions will result from aggregating small number of materials that have a large material forecast mean.

### 6.1.3 Significance

The analysis done in 6.1.1 and 6.1.2 has brought to light the following conclusions:

1. Under the stated assumptions, reducing the SKU number by $x$ will increase the material plan variance by up to $\frac{1}{1-x}$.
2. Decreasing the BOM variability $v$ by $y$ will decrease material plan variance by up to $y$. With best results received when $da_k \sqrt{F_n^k} \ll vF_n^k$.

3. Decreasing the monthly variability coefficient $\alpha_k$ by $z$ will decrease material plan variance by up to $z$. With best results received when $da_k \sqrt{E[F_n^k]} \gg vE[F_n^k]$.

4. Aggregating different materials into one material group of size $|T|$ will decrease material plan percent variability by a magnitude of $\sqrt{|T|}$. With best results received when $|T|$ is large and contains many materials that have a small forecast.

Here, we will discuss the significance of each conclusion, and its effect on the business.

6.1.3.1 **Reducing the SKU number by $x$ will increase the material plan variance by up to** $\frac{1}{1-x}$

This conclusion lies in contradiction to common believe that the decreasing the number of SKUs will increase material plan accuracy. The rationale behind it is that for the material plan, all SKU level forecasts are aggregated either way, and therefore adding another aggregation step before it has no affect on the material forecast variability resulting from the finished goods forecast variability, and has an adverse affect on the variability resulting from the BOM error, since the latter averages out in the second aggregation step.

Company X had conducted several attempts to decrease the finished goods SKU’s number, and observations support that decreasing SKU’s number decreases the per-SKU finished goods forecast. Such initiatives could be valuable to other aspects of operations, such as financial forecast accuracy, or finished goods inventory. However, no data exist on the effect of that SKU aggregation on the material plan. The analysis done in 6.1 assumes that the forecast inaccuracy will grow as a function of $\sqrt{E[F_n^k]}$ and the MAPE will decrease as a function of $\sqrt{E[F_n^k]}$, and shows that in that case, increasing $E[F_n^k]$ through SKU reduction will have a negative effect on the material plan accuracy. Therefore, only in cases where the forecast’s MAPE improves as a function greater than the anticipated $\sqrt{E[F_n^k]}$, SKU aggregation can have
a positive effect on the material plan. It is possible to find some cases in which decreasing the number of SKU’s will have a positive effect on the material plan. For example, on one KC site, the number of SKU’s was so large and the different SKU’s had so little differentiation that the demand analysts complained they could not generate an individual forecast for each of them individually. Under these circumstances it is reasonable to believe that the forecast error will increase slower than $O \left( \sqrt{E[F_{n}^{k}]} \right)$ as $\sqrt{E[F_{n}^{k}]}$ is increased through the SKU aggregations. In that case, SKU aggregation would make sense and have a positive effect on the material plan accuracy. Either way, the analysis suggest that optimization of the finished good forecast process individually will not necessary lead to material plan optimization. Therefore, SKU reduction should be evaluated carefully considering all factors involved, and that its overall affect, not just its affect on the per-SKU finished goods forecast, should be considered. One significant application for the company is to give close considerations to the incentives it applies to its demand planners, and to the demand planning process. In order to ensure to optimization of the entire process, SKU reduction should be regulated and limited, and only be done in coordination with the material planners.

![Figure 11. The absolute error as a function of forecasted quantity and the critical $\sqrt{F_{n}^{k}}$ ratio](image-url)
6.1.3.2 **Decreasing the BOM variability by y will decrease material plan variance by up to y.**

The main conclusion from this part of the analysis is that best material plan improvement will result from inspecting and improving the BOMs of the SKUs that have the largest forecast quantities, the largest BOM errors, or both. This conclusion agrees with common sense, and basically guides the business to deal with the low-hanging-fruit first when readjusting BOM values. At any time, the company has the most to gain by fixing the most commonly used, or the most inaccurate BOMs.

6.1.3.3 **Decreasing the monthly variability coefficient by z will decrease material plan variance by up to z**

Similarly to 6.1.3.2, this part of the analysis concludes that best material plan improvement will result from improving the monthly variability coefficients of the SKUs that have lower forecast quantities and largest monthly variability coefficient. This again, guides the business to deal with the low-hanging-fruit first, inspecting and improving the elements in the equation that causes the most uncertainty.

6.1.3.4 **Aggregating different materials into one material group of size |T| will decrease material plan percent variability by \(\sqrt{|T|}\).**

The conclusion from this part of the analysis is that an effort should be made to create material groups that are as large as possible, and to priorities grouping the materials that are ordered in small quantities. This conclusion is rather obvious, and lies in agreement with current efforts already done within the company.

6.2 **Implementability and Sustainability**

Section 6.1 evaluated the material plan accuracy and how that accuracy will be affected by any improvement in the parameters that the new process aims to modify. Since not enough time had passed, and the process had not yet been fully implemented it was hard to evaluate the effect the new process had on each of these variables and the final material forecast.
However, since one major objective of the internship was to create a process that will be easy to implement and sustainable, I chose to focus on the evaluation of my process along those factors. For this analysis, I chose two tools: the Three Lens Analysis[9] and the Matrix of Change [8][7]. This evaluation process aims to identify and evaluate the new process’s strengths and weaknesses and the tradeoffs made in its design.

6.2.1 The Three Lens

6.2.1.1 Improvements Driven by the New Process:

6.2.1.1.1 Strategic Design

The ultimate goal of the new process, as defined by this thesis, is to enable accurate purchasing of raw material, accurate supplier agreements, and guarantee long-term supply. The new process is strategically better in the following ways:

1. Alignment

Producing an end result that aligns with the strategy of the company

The first step in forming the new process was mapping the needs of the procurement team and defining its desired output. The new process is improving the alignment within the company in three ways:

a. Matching the short term material plan’s horizon with short-term order schedule

b. Matching the granularity of the information with the purpose for which the information is used

c. Matching the accuracy of the information to the accuracy needed by the procurement team.

Therefore, the new process introduced a great advance in customizing and targeting the information generated to the needs of the people using this information.

Aligning Incentives
Not all incentives within Company X stand in alignment with the needs of the procurement team. For example, the marketing team, under certain circumstances, might feel pressured to show a forecast that is as optimistic as possible, rather than as accurate as possible. The new process provides the following improvements to the alignment system:

a. Defining an accuracy objective for the material forecast
b. Tracking the accuracy of past material plans and comparing them to the new accuracy
c. Tracking the accuracy of the finished goods forecast for the entire planning horizon, rather than just 2-3 months.

Matching Resources with Tasks

The new process aims to assure that all tasks are performed by individuals who have the necessary resources to complete them. In the old process, the material planners were required to supply an 18-month raw material forecast when they only had the finished goods information for 4-6 months. They were also required to place material orders for products that are not yet in the system and had to guess which material they would require. The new process introduced the following resource-task improvements:

a. Providing the material planners 18 months of finished goods forecast and BOM information
b. Assigning tentative, un-finalized BOM to newly introduced products before planning for them
c. Providing the demand analysts with strategic marketing information for creating the 18-month finished goods forecast

2. Linking Mechanisms

In order for the new process to work, the information needs to be readily available to all sides. One major improvement the new process introduces is the constant documentation and logging of the forecast information in the company’s system. This allows every planner and buyer to easily access not only the material plan, but all the information that was used to create it.
3. Strategic Grouping

Creating the 18-month material plan requires the involvement of material planners, production planners, demand analysts, marketers and sales people. The new process includes several small-scale groupings to facilitate better information transfer between them:

a. The S&OP Process – This process, also discussed in a past LGO internship engages a cross-functional team with the purpose of generating a well-balanced, reasonable and accurate finished goods 18-month forecast

b. Per-region Implementation Teams – Each country had a sub-team responsible for the implementation of the project, with a regional project manager responsible for coordinating all team members.

6.2.1.1.2 Political

A great strength of the new process is that it was done in collaboration with many major stakeholders and much of their input has been taken into the design of the process. This not only made the process robust and well-thought-out but also increased the likelihood that the new process would achieve vast buy-in and would be easily adopted.

Moreover, most of the change initiatives were done within the planning team, which belongs to the same organization as the procurement team. This guaranteed that the interests of the teams that implement the changes would align with those that benefit from them.

The new process also minimized changes in the shift of within-region power. Even though applying a standard process might compromise the local teams’ perceived autonomy within each country, almost all involved parties retained a similar level of involvement in the process. Therefore, within-region power struggles resulting from the process could be reduced to a minimum.

6.2.1.1.3 Cultural
Being a regional division, the different partners in the project represent unique, individual cultures. While the countries do have several similarities, there are also vast differences and stereotypes that come into play when team members from different regions interact with one another. The major steps that were taken in order to facilitate a successful process, considering the cultural gap, were:

1. Flexibility in Process and in Implementation Plan – Whenever possible, our team allowed the regions to make small customizations in the process and drive the implementation on a different schedule

2. Visibility – Each company’s progress was made visible to each of the other countries, encouraging competition and facilitating motivation

3. Similarity to Old Process and Small Implementation Steps – Since the company culture is focused on results, the process was broken down to small achievable steps, allowing the teams to show progress early on. Moreover, a process that is similar to the old process made the change much easier and faster.

6.2.1.2 Areas of Improvement and Tradeoffs:

6.2.1.2.1 Strategic Design

Alignment

Producing an end result that aligns with the strategy of the company

While the new process does target the needs of the buying team much better and is designed to achieve the business objective, one clear shortcoming of the process is that it does not provide the necessary horizon for well-planned supplier capacity planning. Developing a new supplier to be used by the procurement team could take up to 2 years, and the new process only provides the procurement team visibility to the next 18 months. The cross sourcing team also uses the long term financial forecast, that has a horizon of 18 month to five years, but this forecast in not necessarily as accurate as they need in order to plan for future suppliers’ capacity. In that situation, our team chose to trade
off precise alignment for simplicity and maintaining the fit between the planners’ available recourses and tasks.

Matching resources with tasks

Another compromise that was made in the process was the choice to allow planning for finished products for BOMs that are not yet finalized. This decision forces the material planners to guess and estimate a portion of their material plan. The reason for this trade-off was to allow the marketing team to maintain flexibility and bring new products to the market in reasonable time. Due to the nature of the business and the fierce competition that exists in some of the regions, it is clear that maintaining this flexibility will be vital for the company.

Aligning incentives

As analyzed in this thesis, and discussed in 6.1, optimizing the accuracy of the finished goods forecast by reducing the SKU number would not always optimize the accuracy of the material plan. One way to improve incentive alignment is to mandate that any decision about SKU reduction be done with the participation of the material planners. This assures that any reduction in SKU levels will be done while taking a system-wide view and maintaining the best result for both the finished goods forecast and the material plan.

Strategic grouping

Further improvements to the process could be achieved by assigning a procurement team liaison, which will be tasked with overseeing the process and its implementation and assuring that the end results align with the needs of the procurement team.

6.2.1.2.2 Political

One shortcoming of the new process is that it requires the production planners, demand analysts and material planners to perform additional work. The trade-off here is clear and reasonable, since interviews
conducted within the company showed that the additional work was not significant enough to cause the planners to object to the process, and the stakeholders clearly understood the process’s objective and supported it.

Another shortcoming of the new process is that it compromises some of the marketing flexibility by insisting that new products remain unplanned before a tentative BOM has been developed. While this requirement has not been easily accepted by some of the marketing teams, our team determined that the reduced flexibility would be minimal relative to the additional accuracy and cost savings that this would achieve.

Moreover, initiating a standardized process across several different regions could be interpreted as hampering the independence of the individual countries and regions and cause local push-back. Naturally, our team concluded that a standard process is necessary, and fortunately most of the country managers agreed with us. In certain situations, our team was willing to be flexible and step away from the standard process or the implementation plan to better answer the needs of a specific country and guarantee the continued support of the local team.

6.2.1.2.3 Cultural

Ironically, the main improvement that could be done to the process from a cultural perspective was to have the change be initiated and pushed from the inside, and not by an external English-speaking MIT intern. Many times I felt I encountered additional resistance resulting from being an outsider and failed to understand some of the delicate nuances of some of the meetings. Considering the company’s strong pride and culture, fast and comprehensive changes would be initiated much easier by an insider.

6.2.2 The Matrix of Change
The Matrix of Change[7] is a management tool that is used to evaluate an upcoming internal change in a company. It provides insights into the difficulty of the transition as well as advice on the best approaches to conduct the transition. The MOC was firstly introduced by Amy Austin Renshaw in her LGO thesis in 1993. It was inspired by the House of Quality by J. Hauser and D. Clausing[10].

"The MOC provides a method for determining interrelations among both existing practices and new practices, as well as interrelations between old and new practices. In so doing, seeks to show which practices reinforce one another and which potentially oppose each other. The density as well as the sign of the complementarities guide the user in making it decisions about what changes to make, as well as how, where, and when to implement the selected changes. The tool can be used to help plan a change effort, as well as to assess the progress that has been made midway through a change implementation"
In the next sections, I will present the matrix and analyze the old and the new process using it.

6.2.2.1 Constructing the matrix

1. Identify Critical Processes

At first, we start by identifying the separate most critical sub-processes of the old and new process, and to find the critical sub-tasks of each sub-process.

![Matrix diagram](image)

Figure 13. The critical practices in the existing practices and the new process in Company X

2. Identify System Interactions

After critical processes and tasks have been identified, we will create a triangular matrix that will describe the internal interactions of the old and the new process for each critical practice.
Figure 14. Triangular horizontal and vertical matrixes

Existing practices will be converted to a horizontal matrix, and target practices will be a vertical matrix. Each cell within the triangular matrixes represents an interaction between two processes. A plus sign means that the interaction between the two processes is reinforcing – that one process supports the other, and a minus sign signals two competing or interfering processes – that the practice of one would make it harder to practice the other. With lack of correlation between the processes or lack of information, the cell will remain blank.

3. Identify Transition Interactions

After the internal interactions within each process have been identified, the interactions between the existing and the target processes will be evaluated using a rectangular matrix, as presented in figure 12.
### Figure 15. Transition Matrix

<table>
<thead>
<tr>
<th>Existing Practices</th>
<th>FG forecast generation</th>
<th>Converting FG forecast to RM</th>
<th>NPD</th>
<th>Long term MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short forecast horizon</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Different horizons in each region</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Disaggregating Brand-level forecast to create SKU level</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inaccurate production versions</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Different local MRP versions</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inaccurate BOM</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No material forecast history</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Plan for NPV before BOM is generated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Material planner creates plan</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 4. Survey Stakeholders

The last step of constructing the Matrix of Change involves surveying all stakeholders. A simple five point Likert scale anchored at zero will be used, and the different stakeholders will rank their perceived importance of each subtask in the new process and each subtask of the old process. Since the stakeholder interviews within the company were only done in a qualitative manner, and did not assign a value to each task, I will assign a value myself based on the feedback I received from stakeholders’ interviews.
Figure 16. Stakeholder Survey Presented in the MOC

<table>
<thead>
<tr>
<th>Stakeholder Category</th>
<th>Short-term MOC</th>
<th>Long-term MOC</th>
<th>FG Impact</th>
<th>FG Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Sales</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Operations</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Customer</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Supplier</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

Legend:
- S: Significant
- M: Moderate
- L: Low

Notes:
- Please note that the table above is a simplified representation of the stakeholder survey presented in the MOC.
After completing those four steps, a full MOC could be constructed for the desired process change:

<table>
<thead>
<tr>
<th>Existing Practices</th>
<th>Target Practices</th>
<th>New Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short forecast horizon</td>
<td>-1</td>
<td>-</td>
</tr>
<tr>
<td>Different horizons in each region</td>
<td>+1</td>
<td>+</td>
</tr>
<tr>
<td>Disaggregating Brand-level forecast to create SKU level</td>
<td>+1</td>
<td>+</td>
</tr>
<tr>
<td>Inaccurate production versions</td>
<td>-1</td>
<td>-</td>
</tr>
<tr>
<td>Different local MRP versions</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inaccurate BOM</td>
<td>-1</td>
<td>-</td>
</tr>
<tr>
<td>No material forecast history</td>
<td>+1</td>
<td>-</td>
</tr>
<tr>
<td>Plan for NPV before BOM is generated</td>
<td>+1</td>
<td>-</td>
</tr>
<tr>
<td>Material planner estimates plan</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Figure 17. The Material Planning Process’s Matrix of Change**
6.2.2.2 Matrix Analysis

The following was taken from Management and Scheduling Aspects of Increasing Flexibility in Manufacturing Amy Austin Renshaw [7], regarding the proper way to use and analyze the results of the MOC:

"The sign (where reinforcing is positive and opposing is negative) and density of the interactions in the first triangular matrix supply information about the stability of the old paradigm and the order in which old practices might best be changed …

… The sign and density of the interactions in the second triangular matrix give information about the expected stability of the new paradigm and whether or not the new practices need to be added in parallel or if they can be added sequentially

… The information gained from the transition matrix is the most useful (of the three matrices) for planning the implementation of change. The percentage of positive and negative symbols in the transition matrix indicates how disruptive the change process will be, and, thus, assists in making decisions about where and when to implement change.

… The value ranking and the influence ranking are both indications of how receptive the affected parties will be to the change effort. The value rankings show which old practices are most valued and by which groups of employees, while the influence rankings indicate why employees may or may not be motivated to change to the new practices.”

After constructing the Matrix of Change, we will extract the percentage of negative and positive interactions for the internal and cross processes interaction and use the information to determine the robustness of the old process, the robustness of the new process and the difficulty of the transition. We will evaluate the old and new processes’ perceived value and estimate which stages of the process the teams will be the least motivated to change.
For our matrix, we received the following:

<table>
<thead>
<tr>
<th></th>
<th>Old Process</th>
<th>New Process</th>
<th>Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive interaction</td>
<td>66.6%</td>
<td>37.8%</td>
<td>8.9%</td>
</tr>
<tr>
<td>Negative</td>
<td>5.5%</td>
<td>2.2%</td>
<td>41.7%</td>
</tr>
<tr>
<td>Neutral</td>
<td>27.9%</td>
<td>60%</td>
<td>52.8%</td>
</tr>
<tr>
<td>Overall processes</td>
<td>+1</td>
<td>8</td>
<td>N/A</td>
</tr>
<tr>
<td>importance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.2.2.3 Conclusions

It is clear to see that the old process is much more stable and "sticky" than the new one. The inaccuracy of the data reinforces the "workarounds" the local teams have been creating for the old process, and the workarounds reinforces the inaccuracy of the data. The results stemming from this matrix suggests that the transition from the old process to the new one will be challenging, but the new process will be fairly stable. The new process will also be widely supported as the tasks related to it have a much higher process importance mark.

Another interesting conclusion arising from the matrix is that all the sub-tasks contained in "converting the finished goods forecast to raw material" reinforce one another in the old and in the new process, but interfere with each other in the transition matrix. This indicates that all actions related to that sub-process must be done in parallel and quickly, so the new process will be able to benefit from the reinforcing interaction.

The matrix of change does bring to light the fact that changing over to the new process will be challenging. However, the impact made by the measures and the tradeoffs taken into consideration with the design of the new process is clearly evident. Taking stakeholders' input into account has served to
make a process with very high perceived value. Making the process simple and straightforward made the new process robust and stable, and making the process similar to the old process raised the positive interaction value in the transition matrix. Driving change still presents a challenge, but all measures were taken to minimize its difficulty.
7 Results

7.1 Accuracy Improvement

Since the process is still being implemented, and its accuracy results will only be revealed 6-18 months after implementation, it is hard to determine the accuracy improvement results of the process. In an effort to estimate the accuracy improvement potential of the process, I talked to the various stakeholders and attempted to assign anticipated values to each parameter.

BOM accuracy: With the introduction of the process, BOM accuracy rates have risen from 85% to 90% in several countries (33% error reduction).

Forecast accuracy: In several countries, the S&OP process cut forecast error by 40%.

SKU aggregations: Although SKU reduction efforts are in place in Country five, we proved that SKU aggregation has no positive impact on the material forecast, and therefore will ignore its affect on the material plan.

Looking at this anecdotal evidence, and taking the conservative assumption of decreasing the forecast error and the BOM error together by 20% each, equation [2] $\Delta M_{m}^{k} = \sum_{n=1}^{N}(\Delta F_{n}^{k} \cdot E[B_{nm}^{k}] + E[F_{n}^{k}] \cdot \Delta B_{nm}^{k})$, shows a resulting material plan accuracy improvement of 20%.

7.2 Implementation

The new process has been well accepted by most of the stakeholders and has been implemented rapidly within the company. Four out of the five supply chain managers fully supported the implementation of the new process. A few supply chain managers even vocalized active support and chose to make the implementation of the new process a priority.
Less than 4 months after the new process implementation efforts started, the new process implementation progress was:

Figure 18. Process Implementation Progress by Region, Dec 2010
8 Conclusions and Future Suggestions

In this thesis, we have reviewed the process of designing a new planning process, tools to evaluate the impact of the finished goods forecast and the production error on the resulting material plan, and the trade-offs made when balancing between the new process’s desired outputs with its implementation potential.

The main takeaways from the above analysis refer to the attributes of the material plan, as well as the design of an efficient but implementable planning process.

1. **SKU aggregation decisions should be carefully considered and evaluated, considering its impact on all stages of the planning process**

   While at first glance, reducing the number of finished goods SKUs by eliminating certain product lines has a positive effect on the finished goods forecast, and seem to be increasing the material plans accuracy, that is not always the case. When the BOM error is significant, and the finished goods forecast accuracy increases slower than the square root of the total forecast (as discussed in 6.1.1.1) than aggregating similar finished goods SKU will have a negative effect on the material plan accuracy. Since the material plan is already aggregated across all finished goods, the additional aggregation step improves the sub-process of creating the finished goods forecast, but will not necessary improve the final material plan. When considering finished goods SKU aggregation, the company needs to understand the tradeoffs between finished goods inventory levels (determined by finished goods forecast accuracy), ease of manufacturing, customer demands and the accuracy of the material plan.

2. **Incorporating implementability into the design of new processes will increase process sustainability and ease of transformation**

   Specifically, the consideration of the following should be taken into account when designing a new process:
1. Stakeholders' involvement, opinion and buy-in: involving all the relevant stakeholders early in the design of the new process will have a significant effect on the ease of the process implementation. Looking at the process improvement from the political lens, as well as the survey of stakeholders in the Matrix of Change, it is clear that a process that was designed in full collaboration with as many stakeholders as possibly will have a preferred position of implementability over a process that was designed solely by the task team.

2. Similarity to old process: maintaining as much similarity to the old process as possible will serve to maximize the positive interactions in the transition matrix within the Matrix of Change. This translates to a smoother transition from the old process to the new one, and a higher likelihood of success of the change.

3. Simplicity: a process that is simple will require fewer resources, less training, and is much more likely to have a higher ratio of positively interacting sub-tasks. From a strategic design standpoint, it will be much easier to define new matrices and incentive structures for a simple process, and such process is much more likely to be sustainable.

8.1 The Impact and Significance of the New Process

The new process discussed throughout the thesis was implemented in the five regions of Company X. The new process facilitated a longer, more accurate forecast, as well as better knowledge sharing throughout the company. Using a unified set of IT tools and holding all forecast, BOM and material plan information on the same system will allow visibility throughout the company and help forecast or calculation discrepancies to be discovered. The new process also extends the horizon of the material forecast, and insures manufacturing, planning and marketing teams are involved in the creation of the forecast, which is likely to generate a more accurate forecast. An increased and more accurate forecast will facilitate better
supplier relationships, and will allow Company X’s suppliers to more accurately plan their production, guaranteeing constant supply of raw material.

8.2 Recommendations for Future Internships

In this internship, material plan accuracy, and the process of designing new procedures that support rapid and acceptable change have been explored. Two possible recommendations for future internships are:

1. Explore and analyze the benefit or loss achieved from SKU reduction around the company, and recommend guidelines for when and how SKU reduction should be performed.
2. Design process supporting KPIs that will best support process accuracy and sustainability
3. Implement the proposed process across the five regions, analyze the process implementability, and form new process design guidelines.
4. BOM management analysis – find best practices for BOM maintenance and implement new procedures to insure lower production error.
5. New Product introduction analysis – recognize marketing and manufacturing tradeoffs made in the new process introduction process and make procedure recommendations that will best balance operations with sales.
9 Glossary

CPG – Consumer Packaged Goods

B2B – Business to Business

SKU – Stock Keeping Unit

BOM – Bill of Materials

P&TD - Product and Technology Development

FG – Finished Foods

RM – Raw Materials

FC – Forecast

PP – Production Planner

MP – Material Planner

CA&C – Central America and Caribbean

STD – Standard Deviation

MAPE – Mean Average Percent Error
10 References


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http://ccs.mit.edu/moc/download.html