Establishing an Inventory Management Process to Meet High Customer Service Levels in a Vaccines Organization

By
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Submitted to the MIT Sloan School of Management and the Department of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degrees of

Master of Business Administration
AND
Master of Science in Civil & Environmental Engineering

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Abstract

Inventory management is a complex aspect of Supply Chain Management that is frequently discussed and debated due to the fact that it has a high impact on customer satisfaction as well as financial performance. This thesis addresses how an inventory management policy was developed and established in a vaccines company where customer service is the top priority and product quantities are high.

The work in this thesis is from a six month internship at Novartis Vaccines and Diagnostics in Marburg, Germany. Project work focused on three inventory management questions: What are the right inventory targets for each product? What is the process to manage, monitor and maintain the inventory targets? How should the inventory targets be measured and controlled?

The results from this project show that an effective way to set inventory targets is through the combination of analytical inventory calculations and the strategic analysis of the business environment. A detailed inventory model was built in Microsoft Excel that uses common inventory formulas and considers critical product attributes such as shelf-life, process lead times, batch sizing, replenishment frequency and capacity constraints to calculate the inventory targets. The model results are part of the larger inventory management policy that was created and incorporated into the Supply Chain group's Sales & Operations Planning process. The complete inventory management policy addresses the details of regularly setting inventory targets, how they should be maintained and tracked and defines clear roles and responsibilities.

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The support I received from MIT was also incredible. Without the technical knowledge and expertise of my faculty advisors, professors Don Rosenfield and David Simchi-Levi, there is no way that I could have succeeded in completing my internship and thesis with such high quality results. And, without the incredible LGO 2010 class network, I am not sure I could have kept my sanity during these two years.

Finally, I would like to thank my Mom for her unwavering support throughout what has undoubtedly been some of the most exciting and challenging two years of my life.

Biographical Note

The author, Johanna Christine Wonsowicz, was born in San Diego, California and spent the majority of her years prior to the Leaders for Global Operations Program enjoying the great weather of Southern California. She graduated from the University of Southern California in 2002 with a Bachelor of Science degree in Industrial and Systems Engineering. After completing her degree, Johanna joined Northrop Grumman Integrated Systems in El Segundo, California as an Industrial Engineer on the F-35 Joint Strike Fighter program. Her career at Northrop Grumman brought her through various defense programs and job roles, with her spending her last year working in Finance for the F/A-18 Super Hornet program.

In her spare time, Johanna enjoys being outside, whether it's running, playing sports or reading a book. She is an avid American football fan and barely gets in enough game watching during the fall to sustain her throughout the entire year. She also enjoys traveling and spent six months living in Germany while working on this thesis. During that time, she became conversational in German, learned how to drive a manual car and explored nine new countries.

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1 Introduction & Background

"Keeping healthy people healthy" is one of the mottos heard throughout the Novartis Vaccines and Diagnostics organization. The mission to deliver vaccines that prevent the contraction and spread of serious diseases is one that Novartis employees proudly support. Ensuring that the right amount of each vaccine is available when and where needed is one of the most important aspects of guaranteeing that the company goals are achieved. The challenge of delivering vaccines to diverse international markets with varying requirements is not to be overlooked. As a result, the supply chain strategies for vaccines can be extremely complex.

Within Novartis Vaccines and Diagnostics, the customer is number one. Since shortage of even a single dose of a vaccine could have a large social impact, it is to be avoided at all costs. This focus drives high customer service levels and means that Novartis Vaccines and Diagnostics has taken a conservative approach with inventory levels to ensure that they can meet their customer needs and avoid shortages and stock-outs. This results in high inventory levels, large amounts of obsolete material and unnecessary costs. As Novartis Vaccines and Diagnostics grows, it must (like any organization in a growth period) evaluate current operations strategies to determine what the right strategy is for setting and managing inventory levels in a highly customer service oriented organization.

1.1 Novartis Company Overview

Novartis Group is headquartered in Basel, Switzerland, and employs approximately 98,000 full time employees who work in over 140 countries around the world (About Novartis, 2009). Novartis is one of the leading international pharmaceutical companies and provides a diverse portfolio of products to meet various needs such as: innovative medicines, cost-saving generic pharmaceuticals, preventive vaccines, diagnostic tools and consumer health products. Within the Novartis Group there are four divisions that have been set up to help develop and manufacture the products that meet these needs (Novartis Businesses, 2009):

1. Pharmaceuticals: Innovative patent-protected medicines

2. Vaccines and Diagnostics: Human vaccines and diagnostic tools to protect against life-threatening diseases
3. Sandoz: Generic pharmaceuticals that replace branded medicines after patent expiry and free up funds for innovative medicines
4. Consumer Health: Readily available products that enable healthy lifestyle choices: OTC (Over-the-Counter), Animal Health and CIBA Vision.

1.1.1 Novartis Vaccines and Diagnostics

The Novartis Vaccines and Diagnostics division focuses on developing human vaccines and diagnostic tools to protect against life-threatening diseases. The division has two businesses: Novartis Vaccines and Chiron. Novartis Vaccines, where the scope of this thesis is focused, is the world's fifth-largest vaccines manufacturer and second-largest supplier of flu vaccines in the US. The division's products vary from seasonal flu vaccines to meningococcal, pediatric and travel vaccines. Chiron, the blood testing and molecular diagnostics business, is dedicated to preventing the spread of infectious diseases through the development of novel blood-screening tools that protect the world's blood supply (About Novartis Vaccines & Diagnostics, 2009).

Novartis Vaccines was established in April 2006, following the acquisition of Chiron. Today, Novartis Vaccines maintains a strong global presence (see Figure 1 for a world map of locations) with centers of excellence in Germany, Italy and the United Kingdom. Expansion is also in the near future for Novartis Vaccines; a United States site in Holly Springs, North Carolina is being built to provide the US market with influenza vaccines and protect against demand spikes that result from future pandemic environments. In addition to existing manufacturing sites across the world, Novartis' global presence also includes their customers. Vaccine deliveries span the globe from Greenland to Antarctica and nearly everywhere in between.

Figure 1: Novartis Vaccines and Diagnostics Global Presence

1.2 Problem Motivation

Since the acquisition of Chiron is still in the recent past of the division, Novartis Vaccines is in the process of developing a culture and identity to ensure their position as an industry leader. A large part of establishing this identify involves creating standard policies and best practices for major business processes. As the Novartis sites across the world try to work together to achieve their business goals, many inconsistencies are uncovered and opportunities for improvement are realized. With customer service being one of the highest priorities for Novartis Vaccines, ensuring that inventory levels are set appropriately to meet demand is extremely important and is an area that needs not just consistency across sites, but also formal policies.

1.2.1 Supply Chain at Novartis Vaccines

The Global Supply Chain group within Novartis Vaccines ensures continuous flow of products to customers from the moment of the initial sales order, through production planning and execution, to final delivery at the customer location. For all products, the customer service level goal is 98% of product delivered on time and in full. The Supply Chain group operates under a formal Sales & Operations Planning (S&OP)

process, which ensures customer demand for the next 18 months is supported with manufacturing plans that will deliver the right product, in the right quantities, to the customer on the required date. (Global Supply Chain Website, 2009)

1.2.2 The Specific Inventory Problem

Material within the Novartis Vaccines supply chain travels through four different stages before reaching completion:

1. ***Concentrate Material*** is the active material used during both the conjugation and formulation process.
2. ***Bulk Material*** is material that has completed the manufacturing formulation process and is typically stored in 75 liter steel containers while it waits for filling and packaging.*
3. ***Semi-Finished Material*** has gone through no formulation changes, but has been transferred from the 75 liter steel containers into either a syringe or vial based on customer requirements for packaging.
4. ***Finished Goods*** are achieved when the semi-finished material is combined with a product information leaflet and the proper box for packaging. Once material is in this state, it is typically stored in a warehouse until it is necessary to deliver to a customer.

Figure 2 shows the standard supply chain process that a vaccine follows.

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* In some cases, Bulk Material is used as Finished Goods. This occurs when customers do not require Novartis Vaccines to deliver the product in a filled and packaged form. In this case, the bulk material is transferred from the large 75 liter steel containers to smaller 20 liter glass containers for delivery to the customer.

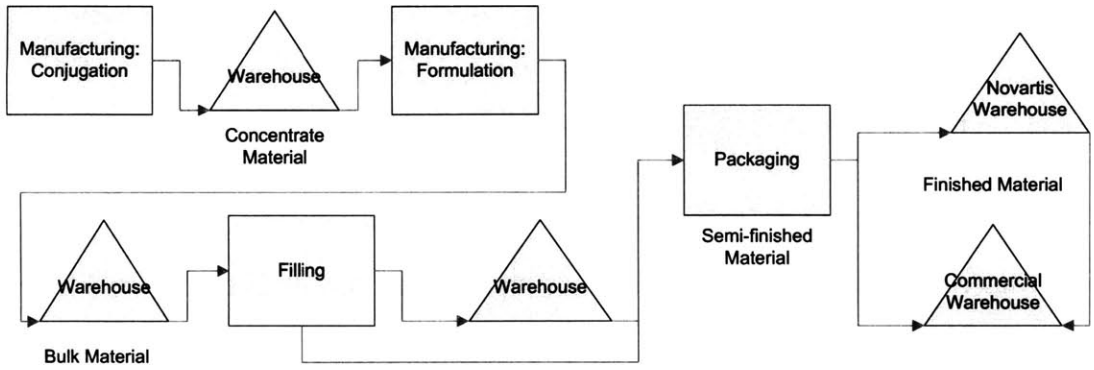

Figure 2: Supply Chain Diagram for a Vaccine

Variations from the standard supply chain described above can occur at any stage of the supply chain since each product will follow the path through the supply chain a little bit differently. To add to this complication, the path followed varies not just by product, but also by customer destination. This requires that care be taken when inventory levels are set as a standard method cannot be applied to every single item.

With high customer service level requirements, Novartis Vaccines has historically chose to carry inventory to serve anywhere between six months and two years demand (this number is selected relatively arbitrarily) to ensure that coverage is available. While this strategy does provide high customer satisfaction, it causes other business issues, such as high obsolete material, and does not consider different strategies for holding inventory at various stages throughout the supply chain.

The need for a formal policy is important not just for developing common standards and processes across the site, but also to establish control and monitoring mechanisms for management to make strategic decisions about manufacturing levels and delivery commitments.

1.3 Hypothesis

This thesis explores different methods to implement a formal inventory management policy in a highly customer focused environment and with hundreds of Stock Keeping Units (SKUs).

A policy of aggregating similar products is analyzed and it is hypothesized that using natural groupings of similar products is the most efficient way to set inventory level policies versus having a separate policy for each SKU.

The final policy will need to provide both an analytical solution and consider non-tangible factors to ensure that the critical attributes of each product grouping are appropriately evaluated.

1.4 Thesis Organization

There are seven chapters contained in this thesis. *Chapter 1* discusses the company background and framing of the inventory management problem. *Chapter 2* explores the current state of inventory management across all of the sites to identify challenges that may occur with future changes as well as to unveil best practices that could be carried across all locations. In *Chapter 3*, the approach used to develop the inventory model and policies is shared in detail. Beginning in *Chapter 4*, the details of the model are described as well as the special considerations that are used to ensure the model is customizable for the supply chain nuances at Novartis Vaccines. *Chapter 5* discusses how the model was incorporated into the Novartis Vaccines organizational processes to ensure sustainability after the completion of this thesis work. *Chapter 6* provides three case studies that share how the model successfully tackles different inventory management problems. Finally, *Chapter 7* summarizes the key findings from the model development and policy setting processes as well as discusses opportunities to further refine and improve the work done in this thesis.

2 Current State Observations

Understanding the current operating procedures is one of the most important steps when trying to establish new processes. There are often assumptions and constraints that drive the current business and need to be understood in order to effectively manage any future change or new process. In the case of Novartis Vaccines, gaining this understanding is challenging because there are three main manufacturing sites across Europe, (England, Germany and Italy) which are responsible for different products, as shown in Figure 3, and therefore each operates with different methods and process.

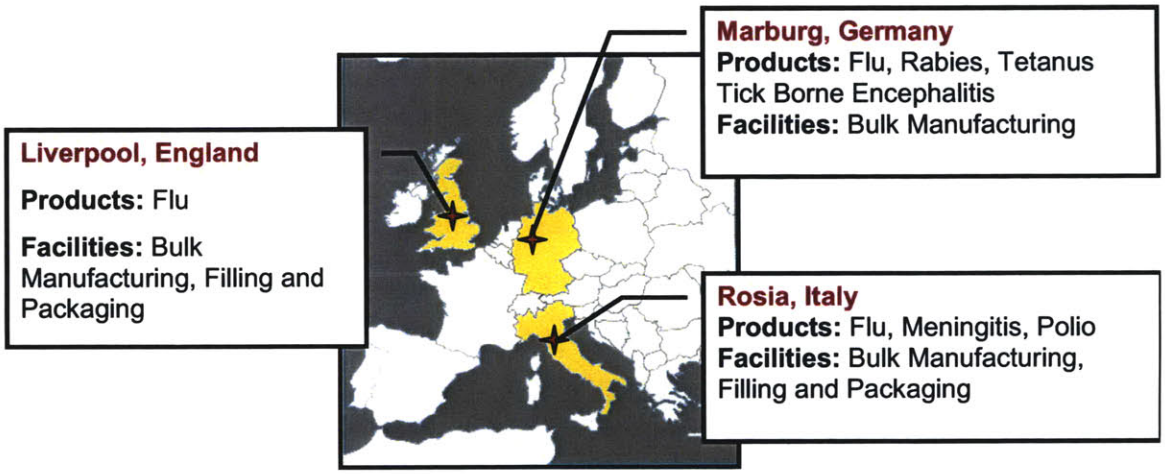

Figure 3: European Manufacturing Sites*

This chapter explores the processes observed at each of the manufacturing sites, discusses what is going well, suggestions for improvement, and addresses potential areas of focus to ensure successful future change.

2.1 Sales & Operations Planning Process

Among all sites, inventory management occurs primarily through the SAP materials resource planning system; however, Microsoft Excel spreadsheets are

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* There is a fourth vaccine manufacturing site in India that produces only one product for India; it is a joint manufacturing venture. There is also a fifth manufacturing site in Holly Springs, North Carolina, which was still being built at the time of this thesis. Neither site is included in the scope of this thesis.

frequently used by personnel to track information that is either not available or has not been fully integrated into SAP. The role of inventory management crosses various departments within Novartis Vaccines and is defined within the Sales & Operations Planning (S&OP) procedures which clearly identify the responsibilities for all key players.

There are two primary organizations that drive the S&OP process: Commercial Supply Chain (CSC) and Production Logistics (PL). CSC is a team of individuals who are the liaisons between the customers, both private and public, and with production logistics. The CSC group is responsible for forecasting product demand in a specific customer area and providing that information to PL in order to allow proper coordination with manufacturing to meet demand requirements. PL is responsible for the process of ensuring that production teams can meet customer demand as forecasted by CSC. PL uses the customer orders to forecast supply and create production plans for each of the individual manufacturing sites. These activities occur every month within the framework of the four phases in the S&OP process:

1. ***Demand Phase:*** During the demand phase, the 18 month rolling forecast (RFC) is updated by Commercial Supply Chain. The new RFC is then uploaded into SAP to be used for the next phase.
2. ***Supply Phase:*** Once the new demand has been updated in SAP, Production Logistics will work with manufacturing at each site to develop detailed supply plans that identify potential supply constraints and confirm manufacturing's ability to meet the customer requirements.
3. ***Global S&OP Meeting Phase:*** When the individual sites have completed their supply plans, they are consolidated into a single S&OP presentation that is reviewed by Global Supply Chain management to address issues and receive approval to move ahead with production plans. Any issues not approved are escalated to the final phase.
4. ***Executive S&OP Phase:*** The final phase of the S&OP process is when issues that were not able to be resolved in the Global S&OP process are brought to the executive committee for their review and decision. The executive

committee will make final decisions during this phase that are then incorporated into either the demand or supply plan, where applicable.

Another important aspect of the S&OP process is the three month frozen period, which dictates that no changes are made to the demand forecast for the current month plus the next three future months. If changes occur during this period, a high level of coordination among manufacturing and production logistics is necessary to ensure that the new demand can be fulfilled.

2.1.1 Demand Forecasting

The forecasting process within Novartis Vaccines, while identified clearly within the S&OP, is the most challenging process for many personnel within Supply Chain.

As discussed earlier, demand forecasts are developed by the Commercial Supply Chain group and are updated on a monthly basis during the S&OP process. Commercial managers (some by site, some by product) are responsible for providing their sales forecast to a single point of contact who integrates each individual demand into a single Microsoft Excel file. In order to develop these forecasts, each commercial manager must rely on their own knowledge about their area of responsibility to estimate future sales. This leads to forecasts which have minimal formal forecasting methods integrated into the final numbers that are input into SAP.

The result is highly volatile demand numbers that the Production Logistics group often questions. Additionally, since a formal tool to track demand forecast accuracy does not exist, there is no data to indicate what type of variability may occur when Production Logistics is creating supply plans.

This uncertainty makes the ultimate goal of achieving high customer service levels even more challenging. In order to successfully manage inventory levels, it is critical to have not only a solid demand forecasting process that all team members support and understand, but also a measure of process accuracy.

2.1.2 Value Stream Process Flows

SAP has the ability to manage much of the data related to the value stream process, including lead times and processing times. In the case of the vaccines process flow at Novartis, each product follows a slightly different path based on where each step in the manufacturing process occurs. Identifying this process flow is challenging; however, it is a critical first step to setting up an inventory process. Table 1 (below) shows a sample of how each product group was documented.

Product Group	Primary Mfg Site	Bulk Storage Location	Filling Location	Packaging Location	Warehouse Location
Group A	Rosia	Rosia	Rosia	Rosia	Rosia
Group B	Rosia	Rosia	N/A	N/A	Rosia
Group C	Marburg	Marburg	Third Party*	Third Party	Marburg
Group D	Marburg	Marburg	Third Party	Third Party	Marburg
Group E	Marburg	Marburg	N/A	N/A	Marburg
Group F	Licensed	Licensed	Licensed	Licensed	Third Party†

Table 1: Sample of Table Used to Identify Process Locations

Once the physical locations of each manufacturing step are understood, it is necessary to associate durations with each process step. While the ideal situation is for the data to be in a system such as SAP for automatic download, the reality is that this does not exist in many organizations, including at Novartis. At Novartis, lead time and process duration data exists in various forms, including: SAP, Excel Spreadsheets, Value Stream Maps, and the brains of the subject matter experts.

Table 2 provides a brief summary of where critical pieces of data exist within in Novartis Vaccines.

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* This is a third party supplier that provides filling and packaging services for Novartis Vaccines. Their services are typically used only for products built by the Marburg, Germany facility during for seasonal production.

† This third party supplier provides warehousing space to store vaccine products which are produced by all European sites; however, are distributed only within the country of Germany.

Process	Data Source
Primary manufacturing	Excel Spreadsheets, Value Stream Maps, SAP
Transportation times	Third Party Logistics Provider database
Secondary manufacturing	Excel Spreadsheets, Value Stream Map
Quality release approvals	Value Stream Maps, Subject Matter Experts
Delivery times to customer	Third Party Logistics Provider database

Table 2: Data Sources for Process Flow Durations

Adding to the complexity of understanding process times is the uncertainty that exists about how and when a process step will be completed. There are three critical process steps which have a high level of uncertainty:

- **Scheduling the filling and packing operations time.** Filling and packing operations exist only at some of the manufacturing sites, therefore, some product's filling and packaging schedules need to be managed by Production Logistics personnel at multiple manufacturing sites. This is a challenge, not just because of the distance, but also because capacity constraints exist throughout the year and are even more prominent when flu vaccines are being packaged.
- **Quality release waiting times.** All of the vaccines must be approved before final release to the customer and sometimes to proceed through the next stage in the manufacturing process. While there are committed durations for this process, there is no guarantee that these times hold for any individual batch. Additionally, when time is critical, it is often possible to expedite these times in order to move more quickly through the process.
- **Yield variation resulting from the manufacturing process.** When formulating a vaccine, the yield that results from the chemical process will vary for every batch. This process variation means that the doses that result from each batch are not consistent. This uncertainty is known by manufacturing and taken into consideration when planning batches to meet customer demand.

For the purposes of this analysis, standard lead time values were used for all calculations since the data was not available to determine the process variation.

2.1.3 Transportation and Warehousing

Transportation methods at Novartis Vaccines are very different for each product. The coordination of material movement within the Novartis supply chain is complex due to location, quantity and quality requirements. As mentioned earlier, a single product could follow dozens of different paths depending on the final customer and the product packaging. An item can be stored within many different warehouses throughout its manufacturing life and this is no different for the Finished Goods stage. Often, once complete, a product will go to a Novartis owned warehouse for a short time before requiring the necessary coordination to distribute it to specific countries and customers, potentially even being sent to an intermediate warehouse location before final delivery.

Warehouse storage is also complex; capacity limitations and locations of warehouses increase the complication of producing and holding inventory. A conservative approach of holding large amounts of inventory has protected the company from unforeseen demand uncertainty; however, product in various stages is stored at approved external locations due to the internal warehouses often being at 100% capacity at peak times. Additionally, operating for an extended period of time at maximum capacity does not allow flexibility as there is no margin for error or movement.

Being able to properly set and manage inventory levels will have a positive impact on the current challenges faced within the Distribution Logistics organization because it will allow them to plan for the future and have foresight into problems that could be faced due to changing inventory levels with certain products.

2.1.4 Finance: Inventory Accruals and Valuation

With millions of doses of inventory being held across the Novartis Vaccines sites, it is important to track and understand the total value of inventory. The Finance group holds the responsibility for this task, including documenting current inventory amounts, processing accruals for inventory that has expired or is lost due to poor quality, and coordinating inventory destruction.

The second task of Finance that is related to inventory management is managing and monitoring the actual costs associated with materials. There are two types of costs that exist for materials and that are tracked in SAP:

- **Standard Prices** are used for goods received from a supplier. Examples of this are packaging materials such as syringes or leaflets, and raw materials such as chemicals used in the manufacturing process.
- **Moving Average Prices** are associated with materials that progress through the manufacturing process. The moving average price is updated regularly when a new batch is produced and new actual data is entered into SAP. When this occurs, the difference between the expected costs and the actual costs are evaluated. For a positive difference between these numbers (when the actual costs are higher than expected), the moving average price will increase, because actual product yield was worse than expected. The reverse occurs when a negative difference results.

The appropriate price is used by Finance to declare the value of inventory in the Profit and Loss statement as well as to accrue product write-offs.

While the interaction between these organizations occurs slightly differently at each site; regular communication occurs and consistent process are being followed.

2.1.5 Metrics

Being able to track and monitor inventory level data is a critical aspect to ensuring the success of setting up a new inventory policy. When this project initiated at Novartis, there were no routine reports being prepared and reviewed for inventory levels across the whole value chain (specific site / section reports were prepared to assist in detailed planning activities). As a result, when questions were asked about inventory levels, a member of the Production Logistics team would need to begin a specific effort to look up all of the needed data before being able to give results to the requester.

During the time of this project, an add-on to SAP, Business Warehouse, was introduced and offered a method to compile demand, supply and inventory data in a single chart for each product. This new tool provides a forecast of inventory levels given

the current forecasted demand numbers. Unfortunately, the tool lacks flexibility for data manipulation and chart design and could not always provide the inventory data needed.

Having a useful metric to monitor and control information is necessary in order to be successful when trying to increase the awareness of and performance in any area. Seeing the weakness in this area highlighted the importance of having a formal inventory policy that not only provides inventory targets, but also creates a foundation to control inventory levels.

2.2 Organizational Assessment

After gaining insight into the critical business processes related to inventory management, it became evident that in order to successfully implement a new policy into the Supply Chain Organization, the environment must be considered. Implementing a new policy with new measurement methods is not usually met with open arms; however, in a young organization like Novartis Vaccines, the opportunity exists to do it right. In order to do this, special consideration was taken to understand the current organizational environment.

The Sloan School of Management at the Massachusetts Institute of Technology, developed a process for evaluating organizations called the Three Lens Analysis (Carroll, 2006). This analysis looks at three areas (lenses) to identify challenges that an organization could face while undergoing change. This analysis was used to understand the risks associated with implementing the new inventory policy.

2.2.1 Strategic Design Lens

The strategic design lens evaluates the formal structure and strategy of the organization to understand if there are any structural conflicts that could prevent project success.

Within the Supply Chain organization, the strategy of the organization is that customer service is priority number one. During the observation phase of the project, this motto was emphasized repeatedly and, it became clear that the costs associated with

carrying extra inventory are not critical compared to guaranteeing that demand requests will always be met.

The Supply Chain group is progressive and management is supportive of change. The current environment is one where new and improved policies are constantly being established to provide better guidance for the current organizational processes. Therefore, implementing a new policy is not something that is unusual at this point in time. However, this project spans multiple organizations. Therefore, even though Supply Chain is responsible for setting and managing the policy, other organizations must be aware of it and be willing to support the same goals and changes.

While implementing this new process does not require any structural changes for successful implementation, it is important that all organizations are supportive and understanding of why new measurements and methods will be put in place. Additionally, the new process does mean that there are new roles for the Supply Chain team members. Therefore, it will be important to ensure that the final policy includes a method for communication and coordination among all of the groups who have responsibility for setting and managing inventory levels.

2.2.2 Political Lens

The political lens considers the different interests and goals that guide individuals, groups, and departments and how those interests might disrupt the intent of the project.

Fortunately, the key stakeholders in the Supply Chain group are supportive of establishing a formal policy and see it as something that is aligned with their own goals. A source of political conflict may exist among the different departments because each group has a different aspect of the process that they feel deserves extra time and consideration. While the ideas brought up by these groups are often relevant and important to the overall success of Novartis, they could not always be incorporated directly into establishing an inventory management policy. As a result, when these types of items were identified, they were documented and many of them either were incorporated either into the formal policy document written for Novartis or are found in

Chapter 7 where opportunities for future work to improve the project results are discussed.

This project does have some additional political impact because the Director of the Technical Operations organization is frequently interested in product inventory levels and strongly supports having a formal policy developed. Having this high level of power encouraging the project forward is a good thing; however, it is important that it does not become the justification for the change and is instead the motivator for finding the best and right way to complete the work.

2.2.3 Cultural Lens

The cultural lens looks at how a change could challenge the cultural norms and values that exist within the organization; thus increasing the risk of successfully implementing a new process.

Because of the diverse countries that NV&D operates in, this may be the most critical lens to understand. It is important to identify the different cultural norms, values and basic assumptions that could conflict with the goals of the project.

One of the primary risks seen is that many individuals believe the transition to create more common processes is a threat to their uniqueness and value. Employees at each site frequently emphasized that their products were different than the other sites and that special consideration was needed. Knowing that individuals felt this way, it became very important to ensure that a final policy offered formality but with enough flexibility that all parties feel their products fit into the framework.

2.3 Chapter Summary

Throughout this chapter, the supply chain processes were discussed, including specifically how they impact decisions related to inventory management. Additionally, three aspects of the organizational environment were explored: cultural, strategic and political. Within the future chapters of this thesis, discussion will continue on how a formal inventory policy is implemented while considering these current business processes and without significantly disrupting the organization's environment.

3 Approach

Once the framework of the problem and the current state of the environment are understood, the discussion about how to develop a solution that fits a given organization begins. This chapter explains the approach used to apply general inventory theories and methodologies to a unique set of organizational and process characteristics.

3.1 General Approach

With the ultimate goal to create a formal policy for management of the inventory for all products at Novartis Vaccines, it became critical to understand the unique characteristics of each product in order to ensure that the final policy could provide useful results for each product. As discussions progressed, it became clear that this could not be achieved with only a mathematical inventory model; but needed to also include a decision process that evaluated a product based on its' unique business characteristics. The combination of these two analyses leads to a complete inventory policy with targets for each product that considers all critical inputs; this approach is shown visually in Figure 4.

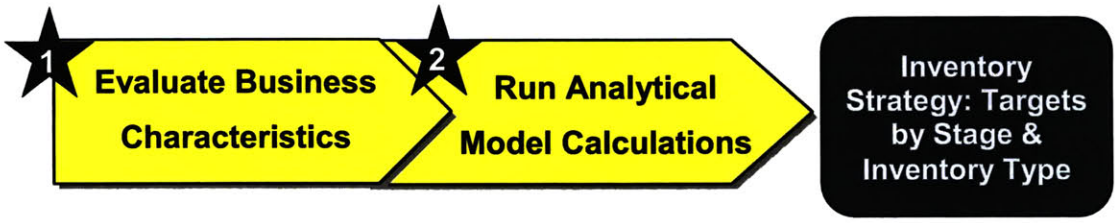

Figure 4: Two Step Approach to Develop Inventory Targets

3.2 Step 1: Evaluate the Business Characteristics

In this step of the model, an individual product is analyzed based on known business characteristics and their impact on the manufacturing of the product. This portion of the analysis is relatively subjective; the results rely on knowledge of all current and future business plans as well as a consistent perception of the impact the interruptions or changes will have on the need to hold inventory for a given product.

3.2.1 Step 1 Model Inputs: Information Sharing

To complete this portion of the analysis, no numerical data inputs are needed. Instead, all personnel who support the product must provide input related to the future manufacturing plan for that product. Questions that need to be answered include:

- What manufacturing stages does this product move through?
- Are there any shelf-life limitations that prevent holding inventory at certain process stages?
- Is the product critical or life saving?
- Is there any known future manufacturing interruptions?
- Is a large amount of demand expected during a time when capacity is limited?
- Are any of the processes extremely unstable?

Appendix 1 shows an image of the user input section of the model that needs to be completed with this information.

3.3 Step 2: Run the Analytical Model

The second step in the process is the analytical model. The analytical model is more complicated than the business characteristics analysis in Step 1 because it requires complete understanding of the manufacturing process, as well as the collection of all of the raw data needed to perform the analytical calculations. A sample of the Step 2 user input sheet can be found in Appendix 2.

3.3.1 Step 2 Model Inputs: Data Collection & Analysis

Gathering the data needed for an analytical model is often the most difficult part of developing a model because the data usually does not exist in the format or level of detail that is required. Additionally, even when the data does exist and is gathered, deciphering its meaning and transferring it into a compatible format to support the model can be a complex project in itself. For the development of the NV&D inventory model,

there are three main areas for which data needs to be collected and analyzed: demand forecast accuracy, process lead times and material value at each stage of the process.

3.3.1.1 Demand Forecast Accuracy

Understanding the accuracy of the demand forecast is critical when setting inventory management policies because it is a measure of uncertainty. Uncertainty drives the need for safety inventory to protect against fluctuations in these processes. When calculating safety inventory, it is necessary to establish an indicator of uncertainty. For demand forecast, this measure is the Root Mean Squared Error (RMSE). RMSE was used for two reasons: First, because there is no known consistent forecast bias. Forecast bias is used here to indicate whether the forecasts are substantially higher or lower than the actual demands. (Silver, Pyke, & Peterson, 1998) And, second, because RMSE is directly related to σ and can easily be calculated using an Excel spreadsheet (Silver, Pyke, & Peterson, 1998) to incorporate into an inventory model. In order to calculate the RMSE, two pieces of raw data* are need:

1. Historical 18 month Rolling Forecast information
2. Historical Monthly Sales data

Once the raw data is gathered and compiled into consistent formats that allow for comparison, the following process (Silver, Pyke, & Peterson, 1998) is used to calculate the RMSE:

1. Calculate the demand error. This is the difference between the actual sales for a given month and the forecasted sales for that month when it was first included in the frozen period.
    i. Ex: Compare January 2009 sales data to the Forecasted January 2009 demand during month of October 2008.
2. Use the RMSE formula to calculate the RMSE for each product.

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* All data is analyzed in the unit of measure: Doses. Dose size may vary based on the product; however, for the purpose of this analysis, it was determined to not be necessary to distinguish this level of detail.

$$RMSE = \frac{\sqrt{\sum_{t=1}^{n} e_t}}{n}$$

Where e = demand error from step 1 and n = the number of months for which the error was calculated.

Equation 1: Root Mean Squared Error Calculation

3. Once the RMSE data is available, it is important to determine the underlying distribution of the forecast errors. If they are normally distributed, a set of readily available formulas can be used within the inventory model. To do this the following steps were used based on the process for validating normal probability and Q-Q plots in the book Statistical Methods for Engineers by Geoffrey Vining (Vining, 1998).

   i. The demand error results for an individual product are sorted in ascending order and assigned a value, i, which is its ranking from 1 through n, where n is the total number of results.

   ii. For each error value, a P_i value is calculated:

$$P_i = \frac{i - 0.5}{n}$$

Equation 2: P_i Value Calculation

   iii. Then, using the P_i for each product and the NORMSINV() function in Microsoft Excel, the Normal Quantile is calculated for each error value. Table 3 shows an example of the complete set of data needed to produce the Normal Probability plot.

Error Data	Data Rank (I)	P(I)	Quantile of standard normal
-208060	1	0,018519	-2,085
-58330	2	0,055556	-1,593
-42630	3	0,092593	-1,325
-38030	4	0,12963	-1,128
-36150	5	0,166667	-0,967
-30800	6	0,203704	-0,828
-29623	7	0,240741	-0,704
-24537	8	0,277778	-0,589
-23450	9	0,314815	-0,482
-21670	10	0,351852	-0,380

Table 3: Sample of Data used for Normal Distribution Test

iv. Using the data in Table 3, the Normal Probability plot is created with the x-axis as the Error Data and the Y-axis as the Quantile of standard normal as shown in Figure 5.

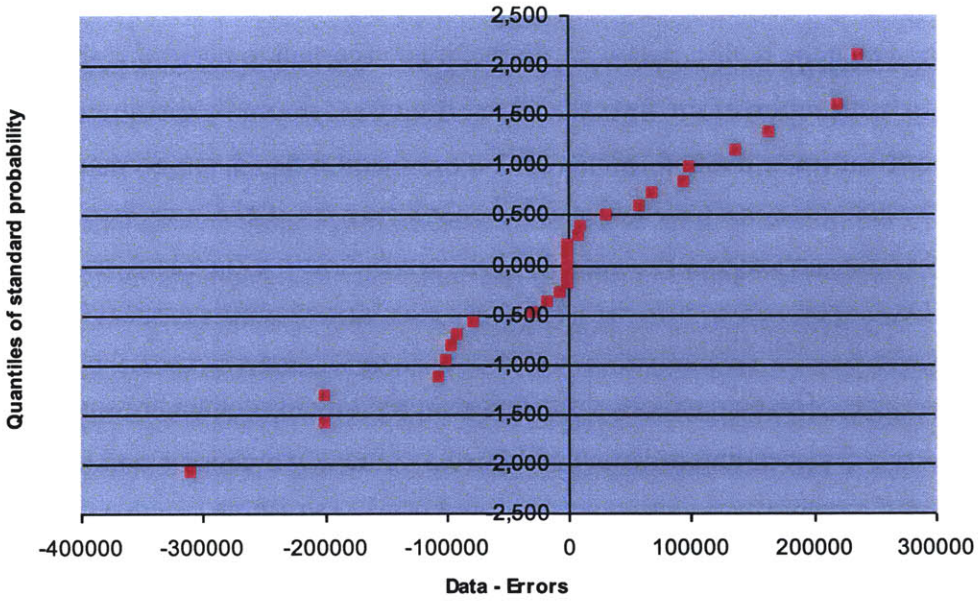

Figure 5: Example Normal Probability Plot

v. The final step is to confirm that the data is normal. This can be done using the "fat" pencil test, which is performed by imagining laying a pencil across the data points on the plot to determine if the data is close to a straight line. If the pencil would cover the majority of the points on the graph, then it can be concluded that the data is normal (Vining, 1998). The chart in Figure 6 shows data that can be concluded to be normally distributed.

After completing this analysis for the forecasted demand data, it was determined that the assumption of a normal distribution is not unreasonable and that the resulting RMSE measurements can be used in the inventory model's safety stock calculations.

3.3.1.2 Process Flow Lead Times

The next set of data needed as an input for the inventory model is the process flow lead times. As discussed in Chapter 2, this data exists in a variety of different sources and at many different levels of data confidence.

For the Novartis Vaccines inventory model, the process flow was broken into eight different detailed lead times that roll into four high level lead times and tie directly to the four main process stages that a product moves through. These lead times are captured as follows:

1. Concentrate Lead Time
    a. Primary Manufacturing process time to achieve Concentrate Material, including quality requirements
2. Bulk Material Lead Time
    a. Primary Manufacturing process time to achieve Bulk Material, including quality requirements
3. Semi-Finished Lead Time
    a. Travel time from Primary Manufacturing Site to Secondary Manufacturing site, if applicable
    b. Secondary Manufacturing Process time to fill material into syringes or vials, as appropriate, including quality requirements
4. Finished Goods Lead Time
    a. Secondary Manufacturing Process time to place product into its final packaging presentation
    b. Batch Release Time
    c. Travel time from manufacturing site to customer location

3.3.1.3 Material Value at Each Process Stage

As the material moves through each manufacturing stage, its value increases and therefore affects decisions one might make regarding what stage to hold the material. At Novartis Vaccines, the Finance group is responsible for maintaining this information and providing the necessary data for the inventory model. Table 4 shows a sample of the level at which the pricing data was collected:

Material Group	Concentrate Material	Bulk Material	Semi-Finished Material	Finished Goods	Unit of Measure	Currency
Group 1	0.61	0.70	1.30	1.63	Dose	EUROS
Group 2	0.20	0.57	N/A	N/A	Dose	EUROS
Group 3	10.19	38.19	45.00	75.00	Liter	EUROS
Group 4	3.72	8.78	10.05	10.56	Dose	EUROS
Group 5	211.35	490.06	635.76	672.30	Dose	EUROS
Group 6	0.10	0.60	4.30	7.10	Dose	EUROS

Table 4: Sample of Pricing Breakdown by Sub Group*

3.4 Data Aggregation

In addition to determining the correct data inputs needed for the model, it is just as important to identify the optimal hierarchical level at which the model should be built. Novartis Vaccines has four product franchises that break into approximately 30 product sub groups which further explode into over 400 SKUs based on country specific packaging and dosage requirements.

It was clear early on that developing the model at the level of the four franchises was far too general. This would ignore many of the product nuances that the Production Logistics planners had identified as critical to making inventory management decisions. The point of discussion occurred around whether the model should be built at the individual SKU level or if the product sub groups would provide enough detail to develop an inventory strategy that consider all the important product characteristics.

As the data and processes became more completely understood, the decision swung towards aggregating the data at the product sub group level instead of leaving it at an individual SKU. Aggregation is the concept of pooling demand for several similar products, which reduces variability because high- and low-demand patterns among individual products tend to cancel one another; thus yielding a more stable pattern of total demand (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006). This is important for the Novartis Vaccines data because the raw data at the product level often

* The data in this table is only provided to represent how cost information was collected and does not represent actual Novartis Vaccines cost data.

lacked information for certain products which resulted in large fluctuations that were likely not accurate representations of reality. With the knowledge from the baseline information gathering, that the demand forecasts have low confidence, it was an ideal opportunity to use a technique that would allow a reduction in process uncertainty, since aggregate forecasts are more accurate (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008).

Finally, the availability of the data solidified this approach decision. As data collection commenced, it became a struggle to find the data at the individual SKU level, and if it did exist at that level, it was often incomplete. However, obtaining information at the product sub group level proved to be an easier task.

These factors resulted in the decision to aggregate the data and build the inventory model at the product sub group level. It is important to note that generally aggregation groups products that are interchangeable for the purposes of distribution during times of product shortage. In the case of Novartis, the aggregate groups include products that are medically similar; however, they may require alternate packaging and labeling depending on the country of distribution. Thus, the inventory targets within this model are most appropriate for unpackaged product or product with one common international packaging.

3.5 Types of Inventory

After defining the key inputs of the model and the level at which the data in the model exists, one last decision about the approach remained regarding the types of inventory that should be measured. Based on the product and business characteristics at Novartis Vaccines, four* types of inventory were identified as critical to inventory management: Work in Process Inventory, Cycle Inventory, Safety Inventory and Strategic Inventory. Table 5 defines each type of inventory.

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* Seasonal stock, which is another common type of stock, was not included in this model as it is felt that fluctuations from seasonal demand is sufficiently considered within the other types of stock.

Type of Inventory	Definition
Work in Process	Ensures the manufacturing pipeline runs continuously to meet customer demand.
Cycle	Completed on hand inventory that exists due to batch sizing during the process cycle and to ensure customer demand is able to be satisfied during that cycle.
Safety	Inventory that protects against uncertainty in customer demand and the manufacturing process.
Strategic	Protects against unique attributes in the normal business environment or within the manufacturing process.

Table 5: Inventory Type Descriptions

(Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006)

3.6 Chapter Summary

This Chapter explained the general approach taken to create an inventory policy for the management of products within Novartis Vaccines' portfolio. Using a two step approach that combines both unique product business characteristics knowledge as well as calculates numerical inventory targets offers a balance of subjective and objective factors that yield an inventory policy that all key stakeholders support. Additionally, the decision to aggregate the data by product sub group provides a model that is customizable for each product that is manufactured but is not so detailed that it would be difficult to sustain the data inputs and thus the quality of the model results.

4 Inventory Model

After setting a clear approach and completing the data collection required for the inventory analysis, the actual model can be developed using the appropriate inventory calculations. This Chapter shares the details behind the functionality of the model, including the methods applied and the special considerations taken due to the company environment. Additionally, the limitations of the model are discussed. This Chapter also provides an overview of the results that are generated through the model, which is the primary source of information that is used for the formal inventory management policy.

4.1 Model Description

As discussed earlier, the inventory model uses a two step approach to determine the best inventory policy for a sub group. The model considers four process stages (Concentrate, Bulk, Semi-Finished and Finished Goods) and four inventory types (Work in Process, Cycle, Safety and Strategic Inventory). Step 1 of the model provides the inventory strategy for a project and Step 2 uses this strategy to generate actual target numbers.

4.1.1 Inventory Target Calculations

The second step of the inventory model performs inventory calculations to determine the targets. The calculations are based on the following formulas and methods.

4.1.1.1 Work in Process Inventory

Work in Process (WIP) inventory is the flow of units being processed in a manufacturing or service operation (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006). The calculation used to determine WIP inventory is:

$$\text{Invetory}_{WIP} = AverageDailyDemand * ManufacturingStepOperationTime$$

Equation 3: Work in Process Inventory Calculation

4.1.1.2 Cycle Inventory

Cycle inventory must exist in this model because the process steps are processed in batches both during production and transportation. Cycle inventory is the average inventory that arises due to batch activity (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006). The calculation used to determine cycle inventory is (for the purpose of this model, the Period equals one month):

$$\text{Inventory}_{\text{CYCLE}} = DemandDuringPeriod \div 2$$

Equation 4: Cycle Inventory Calculation

4.1.1.3 Safety Inventory

Safety inventories are maintained to protect the process and customers from unexpected supply disruptions or changes in demand (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006). The calculation for safety inventory is:

$$\text{Inventory}_{\text{SAFETY}} = z * RootMeanSquaredError * \sqrt{LeadTime}$$

Equation 5: Safety Inventory Calculation

(Simchi-Levi, Kaminsky, & Simchi-Levi, 2008)

The Root Mean Squared Error is based on the Demand Forecast accuracy, which was discussed fully in Section 3.3.1.1. The value of z is the standard normal random variable based on the Customer Service Level (CSL). CSL is defined as the probability that there will be no stock outs within an order cycle (one month) (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006) and is most frequently measured as a percentage value. An alternative method to measure customer service is by percent demand satisfied directly from stock; while it is also a percentage value, it is a different way to measure customer service level. For this inventory model, the first method most accurately represents how customer service is measured and monitored at Novartis Vaccines and the inventory model is set up to allow the user to input an appropriate CSL based on specific service agreements.

4.1.1.4 Strategic Inventory

Strategic inventory protects against unique attributes in the normal business environment or within the manufacturing process that cannot be incorporated into the calculations for any of the three previous types of inventory. Within this inventory model, it is assumed that strategic inventory will be a decision that management makes based on known product characteristics or future events that would have a large impact on decisions related to inventory, such as the transition of manufacturing operations from one facility to another. For this reason, the model is setup to allow the user to input the specified amount of days of strategic inventory that need to be carried to protect against the business variations. The resulting calculation for strategic inventory is:

$$Inventory_{STRATEGIC} = AverageDailyDemand * NumberofDaysofStrategicCoverage$$

Equation 6: Strategic Inventory Calculation

4.1.2 Multi-Echelon Inventory Systems

Similar to most other supply chains, the Novartis Vaccines supply chain has multiple manufacturing steps and process stages that although owned by Novartis, often occur in different countries and manufacturing facilities. Within supply chain management, this type of inventory system is commonly referred to as a multi-echelon inventory system. (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008)

In the Novartis Vaccines supply chain each of the four stages in the process has its own lead time as well as its own team responsible for monitoring and managing the process stage. Visibility of inventory levels at all of the locations exists in a single source; however, past inventory decisions were often made by different levels of management causing conflict between how each stage was managed and operated.

For a multi-echelon inventory policy to be effective, it is necessary to assume that (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008):

1. Inventory decisions are made by a single decision maker
2. The decision maker has access to inventory information at each location

Although this has not always been the case at Novartis Vaccines, the move to a single inventory management policy is aligned with these assumptions and helps to ensure the policy's success.

4.1.3 Application of Strategic Inventory Placement Model Ideas

The strategic inventory placement (SIP) model was developed by Dr. Stephen Graves at MIT and is used to determine the amount and positioning of inventories in a supply chain (Graves & Willems, 2000). Within the inventory model developed for Novartis Vaccines, principles from the SIP model were applied related to process stage coupling and lead time calculations. Lead time values were determined based on which stages inventory is to be held. If inventory is not held at one (or more) stages of the process, then the associated lead time for that process stage must be accounted for elsewhere in the inventory calculations, in other words, the two process stages are coupled. Table 6 shows a simple example of how this works:

Stage	Standard Lead Time	Carry Inventory? (Yes/No)	Adjusted Lead Time
1	5 days	Yes	5 days
2	5 days	No	N/A
3	5 days	Yes	10 days
4	5 days	Yes	5 days
Total	**20 days**		**20 days**

Table 6: Lead Time Calculation Example

In this example, since no inventory is carried at Stage 2, the five days of lead time associated with that stage are coupled with the next stage in the process where inventory is held. And, safety stock at Stage 3 must cover the increased 10 day lead time. This results in the same total lead time for the entire process.

When considering whether inventory is held at the final process stage, the required delivery time to customer must be compared to the actual amount of time it would take to get the product from its current state to the final state. If that manufacturing time is greater than the agreed delivery time after an order is placed, then inventory must be held at the finished goods stage (Graves & Willems, 2000). Although quality

requirements for vaccines often increase standard lead times to many days and even weeks, the actual manufacturing time for the final two stages within the Novartis Vaccines process could potentially occur within a single day. Thus, with management's agreement that this is not a risk, the model allows users to make the decision to not carry inventory at the finished goods stage.

4.1.4 Periodic Review, Order-Up-To-Level Inventory Model

As discussed earlier in this thesis, Novartis Vaccines has a strong Sales and Operations Planning process in place that follows a monthly review cycle. This means that inventory levels, demand forecasts and production plans are reviewed once a month. This type of regular review is defined as a periodic review system; between each S&OP process, there is uncertainty related to inventory levels (Silver, Pyke, & Peterson, 1998).

Based on the profile of the Novartis Vaccines supply chain, the inventory model is structured as a Periodic-Review, Order-Up-To-Level System (R, S). In this type of system, the control procedure is that every R units of time (for this model, R = 1 month) an order is placed up to the quantity level of S (Silver, Pyke, & Peterson, 1998). This inventory model calculates the S value based on the user inputs defined in Chapter 3 and the formulas explained earlier in this Chapter. Since the calculation for the Order-Up-To-Level, S, includes all four types of inventory (Work in Process, Cycle, Safety and Strategic), it incorporates all of the key factors related to the supply chain into the target inventory level.

4.2 Other Model Considerations

In addition to the standard inventory calculations included in the analytical inventory model, there are a number of other aspects of the manufacturing process and products in the Novartis Vaccines environment that need to be incorporated into the model to ensure completeness: Product Seasonality, Shelf Life, Manufacturing Capacity Constraints, Batch Sizes and Flexibility for What-If Scenarios.

4.2.1 Product Seasonality

As discussed earlier, the Sales and Operations Planning process runs on a monthly cycle and produces rolling forecast (RFC) demands for an 18 month period. These rolling forecasts are actively used by the entire Supply Chain organization for manufacturing, distribution and warehouse planning. The 18 month demand RFC provides an easy way for teams to see demand fluctuations and seasonality which exist because of seasonal illnesses, such as flu in the winter. Or, for products that are geared toward travelers, peak seasons may exist just before the summer months. These types of fluctuations in demand can be large and therefore, are critical to the model.

In order to ensure that proper consideration is taken for product seasonality, the 18 month demand RFC is a direct input into the model. All calculations that rely on average monthly demand are tied directly to the forecast demand for that 18 month period. This integration into the model allows the user to easily see the impact on inventory that results from a product's seasonal changes. Additionally, when demand changes occur, this direct link to the demand data allows for immediate visibility to the impact that demand change has on the projected inventory levels.

4.2.2 Product Shelf Life

Each product has a different shelf life that must be monitored when product is stored at each inventory stage. For example, some products cannot be held at a stage for any longer than 24 hours because of instability in that state. In this case, the business characteristics analysis allows the model user to clearly input these constraints.

The more complicated aspect of inventory shelf life is ensuring that the inventory on hand at any given stage does not exceed the expected demand for a product within its known shelf-life. If this were not checked, a company could be at risk of carrying much more inventory than can be sold before the product expires. Therefore, within the model, special logic has been put into place to check the recommended inventory levels against forecasted demand over the expected shelf life. If the inventory value is greater than forecasted demand in that period, the model will indicate that the inventory is at risk.

This allows the user the opportunity to modify their inputs and re-run the model or to move ahead with the knowledge of the risk.

4.2.3 Production Capacity Constraints

All manufacturing operations are limited by their production capability and vaccine manufacturing is no different. The model is set up to run in its base state assuming infinite capacity; however, since infinite capacity is not usually realistic, the user can modify the input sheet to indicate any areas where the recommended inventory amounts exceed the identified process capacity. The model then uses this data to modify the Work in Process during any period where capacity is limited and spreads the inventory required across any periods with excess available capacity. While this is not a perfect representation of the manufacturing operations at Novartis vaccines, it does offer a satisfactory way to model how capacity management decisions are made. Thus, providing a useful tool to help management see how the constraints impact the inventory plan.

4.2.4 Batch Sizes

Vaccine manufacturing occurs in batch sizes, both during primary and secondary manufacturing. Although the model is set up to calculate inventory based on doses, knowledge of batch sizes is important when developing manufacturing plans. Therefore, the model provides output both in number of doses as well as in number of batches for each process stage.

4.2.5 Flexibility for What-If Scenarios

Although standard data exists for process lead times, it was determined that having the ability to change lead times to see the effects on the results would be valuable. Thus, the model was designed to allow users the ability to change the lead time for an individual product or even for just a single process step for a given product. The model's default, however, is to use the standard values. The use of these input fields allows one to easily perform What-If scenarios and comparisons to understand how a process improvement or change would impact the inventory levels.

Strategic inventory is also an area where flexibility to input data is useful, and this too is incorporated in the model. If a step has been identified as requiring strategic inventory, the user must enter the amount of days of coverage that is required. Again, this number can easily be changed or removed in order for the user to understand the impacts to inventory levels.

4.3 Model Limitations

Although the model successfully combines many traditional inventory management calculations with specific factors related to the Novartis business, the level of customization leads to the exclusion of other inventory management attributes that should not be ignored. While many modeling decisions are related to the availability of data, as has been discussed at points earlier in this chapter, the two limitations identified below were based primarily on the requirements of the user. However, it is still important to understand these limitations especially when considering both the results of the model as well as further opportunities for model improvement.

4.3.1 Individual Process Stage Service Levels

In this inventory model, the customer service level (CSL) used is specific to the availability of finished goods in the final warehouse. As a result, the safety stock calculations for each stage use this finished goods CSL. This is a simplification of true customer service levels. In reality, the service levels of each individual warehouse further upstream in the process should vary due to process lead time. Fortunately, within Novartis, the standard CSL that is planned for is 98%, which is shown to not significantly vary the upstream CSLs (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008). Thus, it is not unreasonable to exclude this level of detail from the model.

4.3.2 Optimization of Stage Selection

Stage selection for where inventory is to be carried has been set up in this model in a way that allows the user to drive the results based answers to the Step 1 business characteristics questions. While this allows the user to understand how business decisions could impact inventory management, it does not necessarily lead to an optimized

inventory strategy. In order to allow the model to optimize the stage selection, certain flexibilities that the user requested would need to be removed as well as trust in the raw data would need to increase.

4.4 Inventory Model Results

As a result of the formulas described above and the other attributes considered in the model, there are two types of results generated for the user to analyze. The results from the first step are from the strategic business analysis, which provide the overall strategy for carrying inventory. From the second step comes the actual inventory target numbers, which rely on the strategy results from the first step.

4.4.1 Step 1 Output: Business Characteristics Results

In Step 1, the recommended inventory strategy is provided by inventory stage (Concentrate, Bulk, Semi-Finished and Finished Goods) and by inventory type (Work in Process, Cycle, Safety and Strategic Inventory). A sample of the output from the model is shown in Figure 6.

Recommended Stages and Types of Inventory to Hold

	Concentrate	Bulk	Semi-Finished	Finished Goods
Work in Process Inventory	Yes	Yes	Yes	Yes
Cycle Inventory	Yes	No	Yes	Yes
Safety Inventory	Yes	No	Yes	Yes
Strategic Inventory	No	No	No	No

Figure 6: Step 1 Model Results

As indicated above, the results from Step 1 are used as a direct input for Step 2.

4.4.2 Step 2 Output: Analytical Model Results

The analytical model results provide the detailed target numbers that are critical to setting an inventory management policy. The output sheet provides the following information and can be seen in full in Appendix 3:

- Average Monthly Inventory Levels for the 18 Month RFC Time Frame
    - Averages are shown by inventory type and process stage

- Strategic Inventory Levels for Each Month in the 18 Month RFC Time Frame
- Shelf Life Validation
- Average Monthly Inventory Costs

The results in this output sheet align directly with the variables needed to support a Period Review, Order-Up-To-Level policy. The average monthly inventory levels in the output sheet are the values that should be used as the S, or Order-Up-To-Level value.

4.4.3 Chart-Results Output

Although during the course of this project it was not possible to link real time data with the inventory model to create charts for control and measurement, an output sheet was developed to provide a visual view of the targets for the next 18 months. (Additionally, in Chapter 5, there is further discussion about effective ways to establish real time visibility that would support the inventory model and policy.) There are three charts, which display the inventory target information as follows:

1. All Up Inventory Targets (Figure 7): This chart shows the total inventory target for the specific product, both the monthly target value and the average target value for that 18 month period.
    a. There is also an input area that allows the user to manually input the current Inventory On Hand information in order to see it displayed on the graph and compare it to the targets.

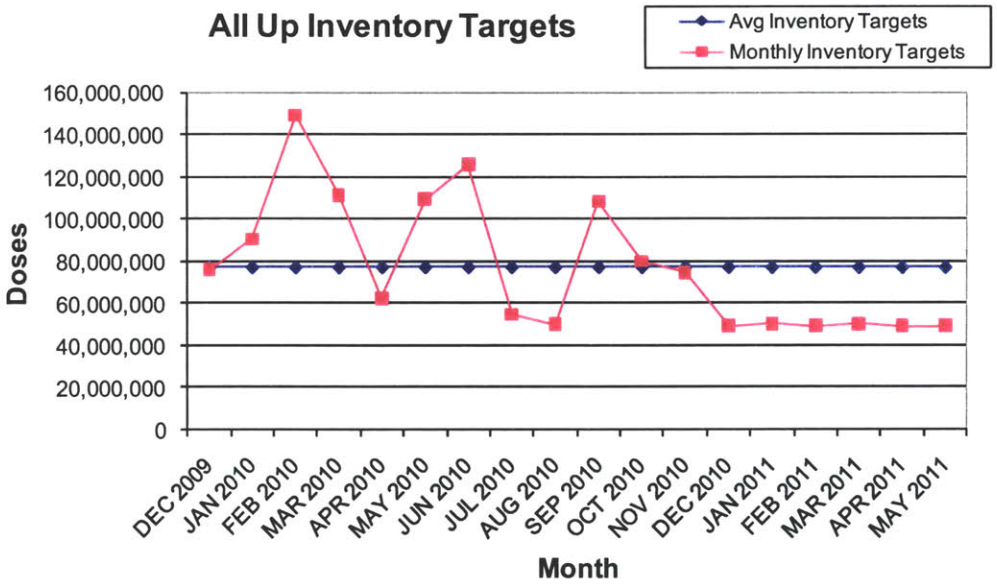

Figure 7: Results Chart - All Up Inventory Targets

2. Inventory Targets by Type (Figure 8): This chart also provides both the monthly and average product inventory targets; however, for the monthly values, the graph shows the breakdown of inventory type that makes up the total value.

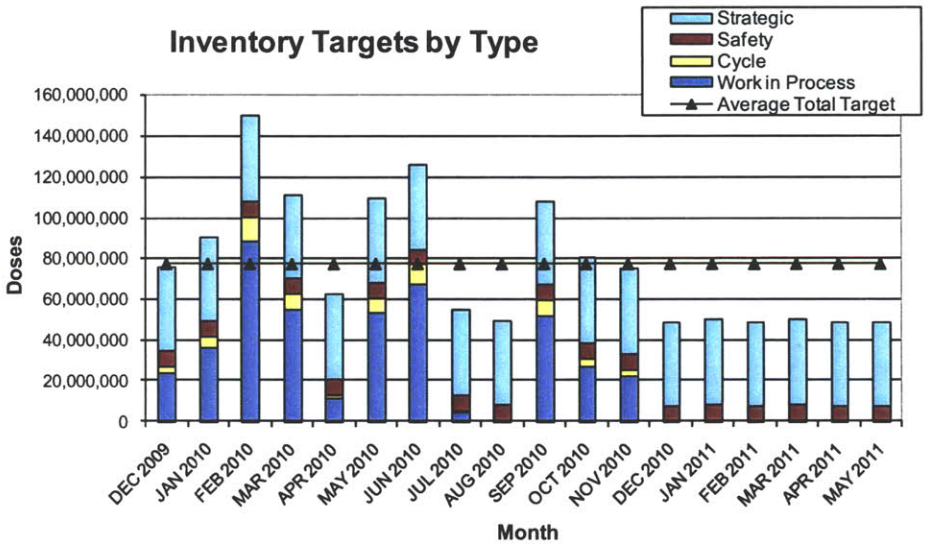

Figure 8: Chart Results - Inventory Targets by Type

3. Inventory Targets by Stage (Figure 9): The third chart also displays both monthly and average inventory targets; however, in this chart, the monthly targets are broken down by inventory stage instead of type.
    a. Additionally, if the user chooses to manually input the current actual inventory data, this chart is setup to display the current data compared to the targets by inventory stage.

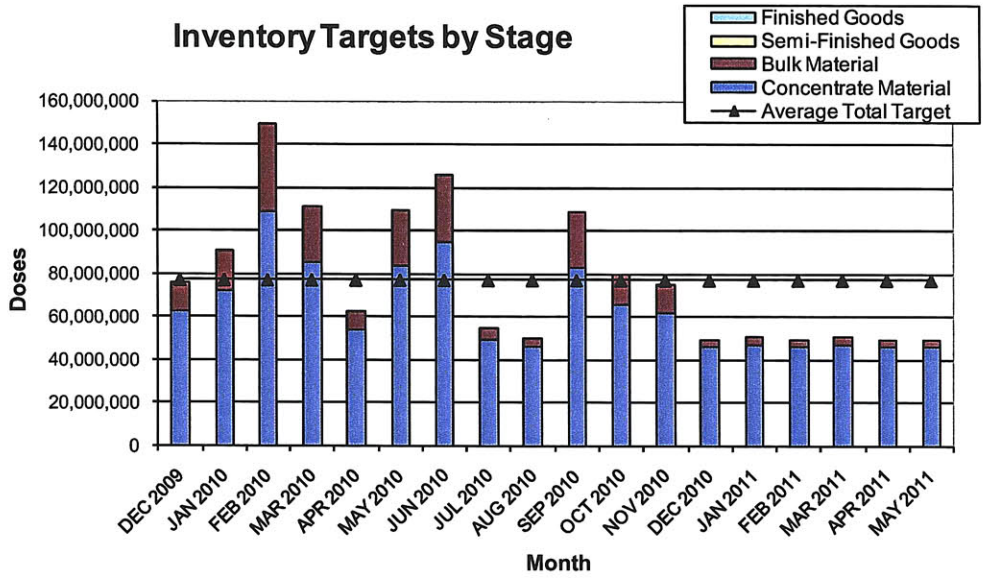

Figure 9: Chart Results - Inventory Targets by Stage

With the combination of the detailed data results from Step 2 and the chart results described here, management and production logistics team members have various ways to look at the inventory targets and understand the data in order to set a future manufacturing plan.

4.5 Chapter Summary

This Chapter explains the details of the formulas used to calculate the inventory targets as well as discusses the special considerations that the model evaluates to ensure an accurate representation of the Novartis Vaccines environment. The results of the model were also introduced, offering the first glimpse at what type of information the user receives from using the model.

5 Model Implementation and Policy Development

Ensuring continuous use of a new process or model is often the most challenging aspect of implementing it within an organization. In order to ensure successful integration within Novartis Vaccines, a formal policy was developed to guide use of the model and align the new inventory management tool with the Sales & Operations Planning process.

5.1 Sensitivity Analysis

A critical aspect of using the inventory model successfully includes understanding the different variables that can change and the affect that those changes have on the resulting inventory targets. This is especially important information when performing What-If scenarios and evaluating the results from each scenario. Table 7 provides a summary of the sensitivity for the most critical user variables. See Appendix 4 for an example of the calculations used to determine model variable sensitivity.

Input	Level of Impact	Inventory Impact if you Increase the Value	Inventory Impact if you Decrease the Value
Demand Forecast Accuracy (Root Mean Squared Error)	High	Increases	Decreases
Strategic Inventory Days of Coverage	High	Increases	Decreases
Frozen Period	Medium	Increases	Decreases
Lead Times	Medium	Increases	Decreases
Order/Batch Replenishment Frequency	Medium	Decreases	Increases
Capacity Constraints	Low	Net inventory quantities do not change, but quantities are distributed differently across the months.	
Customer Service Level	Low	Increases	Decreases

Table 7: User Input Variable Sensitivities

5.2 Formal Documentation

Developing only an Excel-based inventory model that performs inventory analysis does not fully address the challenge of creating a business process for inventory management. There are many issues related to inventory that cannot be programmed into

an Excel spreadsheet. Additionally, there are many questions that arise regarding how to manage, monitor and control the inventory model and who is responsible for these tasks.

At Novartis Vaccines and Diagnostics these additional considerations were best addressed by creating a formal inventory management policy. The policy provides guidance on how the inventory model should be used to set inventory targets and provides details related to ensuring that the model is properly sustained to ensure usefulness for the business not only today but also into the future. In addition to explaining model functionality, the policy clearly defines the roles and responsibilities of supply chain personnel as well as the change management process for both the model itself as well as the targets that result from the model.

Most importantly, the formal policy document provides a single location for anyone to view the agreed to inventory levels for each sub group. This eliminates confusion that often results from products being manufactured at multiple sites or changes in management.

5.3 Inventory Measurement

Following the process and using the model regularly to develop an inventory strategy and actual targets is a step in the right direction. However, having inventory targets alone does not provide enough information to make management decisions or to determine if actual inventory levels are good or bad. Thus, establishing a method to measure actual inventory levels against the formal targets is a necessity. At Novartis Vaccines, the use of SAP and Business Warehouse provides a tool that can link the targets and the actual data. During this project, the different types of measurements needed were identified; however, the complex business systems work was still required to complete the link between the two systems.

5.3.1 Use Real Time Visibility to Monitor Current Inventory Performance

By linking the real time data in SAP with the current inventory targets developed by the inventory model, anyone would have the ability to compare the inventory targets with current actual inventory levels to determine if there is risk of not meeting the current months' demand. Figure 10 shows an example of this chart.

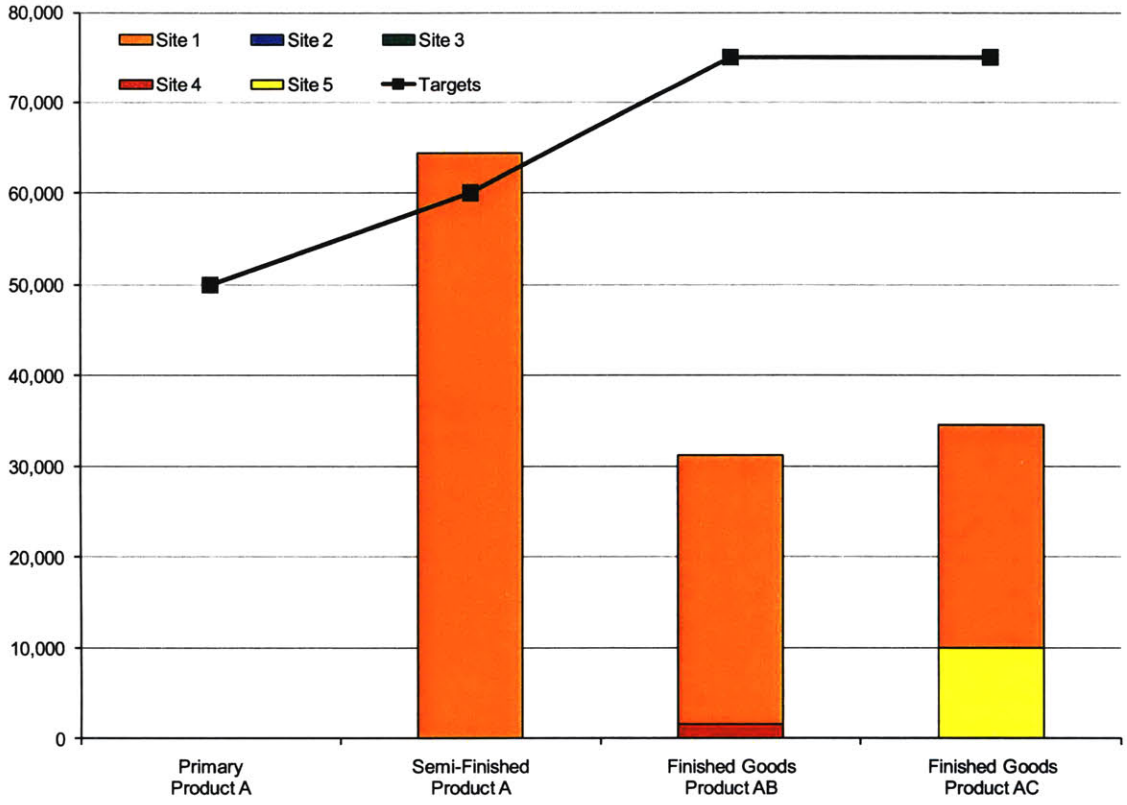

Figure 10: Chart of Inventory Targets versus Actual Inventory Levels

In this example, it is evident that this product is at high risk of satisfying demand. The Finished Goods inventory for both Product AB and AC is well below the targets. Additionally, early on in the process, at the Primary level, there is no current product in inventory.

5.3.2 Use Real Time Visibility to Plan for the Future

In addition to monitoring inventory in the current period, it is also useful to measure the future target projections against the expected future demand and supply profile. Doing this comparison can help identify potential inventory gaps and help drive necessary planning changes in order to avoid future problems. In Figure 11, an example of this chart is shown.

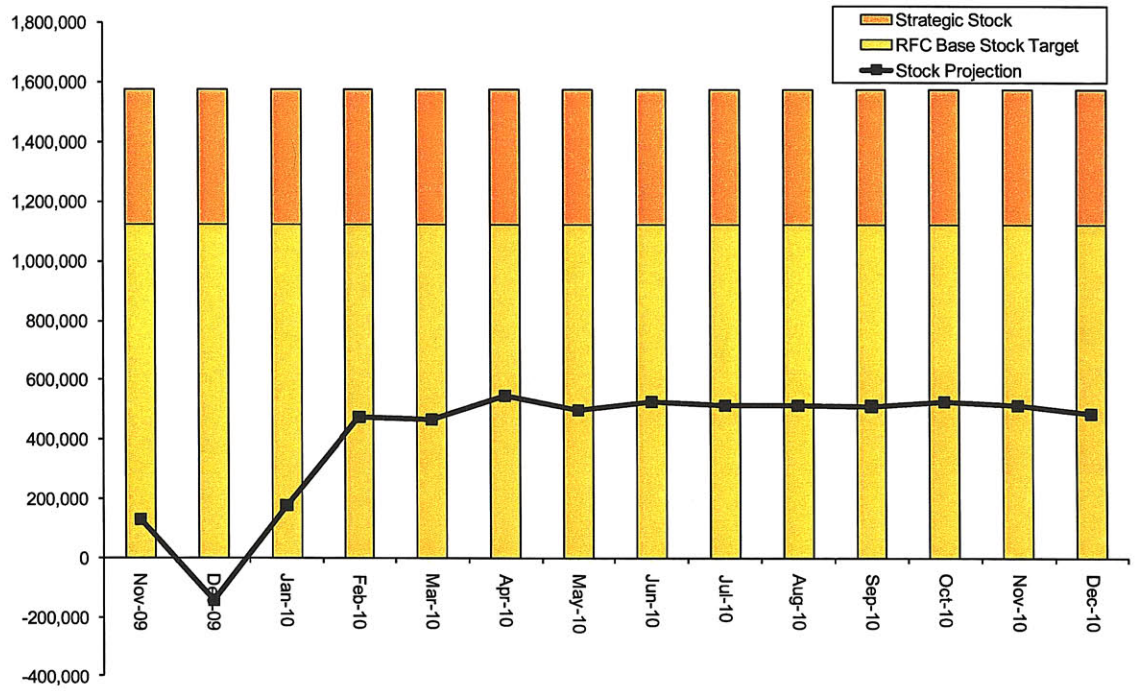

Figure 11: Chart of Future Inventory Projection Compared to Targets

From this example it can be seen that the product is forecasted to be in a shortage during the next month. And, with the current planned future production, the actual inventory levels will be well below the targets.

5.4 Organizational Considerations

Setting up the framework and tools needed to properly manage inventory is often seen as the most challenging aspect of improving inventory management in an organization. Any new process or organizational change will not be successful without fully addressing the impact that it has on the current group members and processes. In the case of Novartis Vaccines there are four main activities where focus needs to continue within the organization now that the formal policy is in place:

1. **Employee mindset must be consistent with process guidelines and the overall strategy.** The implementation of this new process means that there must be more value placed on proactive management of inventory versus reactive responses. Employees at low levels should be willing to add this new tool into their set of skills and see it as a way to help avoid future challenges not as an added task that

only makes their day busier. Without alignment across all levels of the organization, the group members will go their own way (Klein, 2004) and, thus, the likelihood of a successful implementation will decrease.

2. **Stakeholders support and encourage the use of the inventory management process.** It is critical that all levels of management have a consistent view on the value of this new process for managing inventory targets and that they publicly support and encourage its' use. Stakeholder alignment is critical in creating a receptive environment for change (Klein, 2004).

3. **Integrity of the data used in the inventory management process is constantly challenged and pushed to be more accurate.** A model is only as useful as the data that is put into it. The current version of the model relies on demand forecasts that Production Logistics personnel are not sure the accuracy of; increasing robustness in the demand forecasts will increase trust in the inventory model results. Additionally, the model relies primarily on manual inputs of the raw data. Improvement of the use and maintenance of the data in SAP could allow a direct link between the model and SAP which would help eliminate the risks of data error due to the manual process.

4. **Continuous improvement of the model to allow for increased process sustainability in the long term.** The inventory management policy places process responsibility in the right role for each product and site. It is critical that the responsible people update the model as agreed to and actively participate in providing feedback on how the model could be improved. Continuous improvement, which is the process of implementing ongoing incremental improvements in the process (Anupindi, Chopra, Deshmukh, Van Mieghem, & Zemel, 2006), is an important part of operating as an efficient organization.

5.5 Chapter Summary

Chapter 5 has focused on discussing how the work done in this thesis can be implemented and sustained throughout a large organization. Considerations include both business process and organizational structure. The implementation of a formal inventory

management policy shows that the model can be integrated into a policy that can be used by management to track and measure performance and ultimately to help position the organization and the company for continued success.

6 Case Studies using the Inventory Model

In order to validate the results of the inventory model as well as demonstrate model usability for products that face unique inventory management challenges, three Novartis Vaccines products were analyzed with the inventory model. This Chapter discusses the challenges faced by each product and how the model was used to help answer questions and overcome challenges for each product.

6.1 Product 1 Case Study: Setting Targets with High Process Uncertainty

Product 1 is manufactured at the Marburg, Germany site but is filled and packaged both in Germany and in Italy. It has a yearly demand in 2010 of approximately 1.5 million vaccines that are to be delivered primarily across North America and Europe. Product 1 is considered to be a life saving product and thus requires extra emergency stock to be carried in case of an event that requires a large amount of the vaccine in a short period of time.

6.1.1 Product 1 Current State

Currently, the product inventory levels and manufacturing production rate is not at a level that is meeting the required customer demand. This is driven primarily by lower than expected production yields due to an increase in recent quality issues. Additionally, the current stock level for Product 1 is much lower than normal as the product was recently shutdown for three months; therefore, the quality issues arose during the ramp up period. Furthermore, although there is excess product in storage to prepare for the three month shutdown, there two problems faced with this stock:

1. In the finished goods state, the product is country specific and cannot be sent to another country when it has already been packaged in a specific presentation for the original destination.
2. Although the product shelf-life is four years, the remaining product is less than a year away from expiration and many customers will not accept it.

These challenges have lead Production Logistics personnel to have to act quickly to try to secure additional manufacturing time as well as push on Quality Assurance to review the material failures and help identify solutions that can allow product to be approved for sale and return the process to its regular performance level.

6.1.2 Product 1 Problem Statement

While the issues of the past cannot be erased, it is important to determine how to ensure a problem like this does not occur again in the future. Additionally, next year's capacity is expected to be in far excess of the forecasted 1.5 million doses of demand. This means that although inventory levels could be built to protect the product from stock out risk, the question still remains: What are the right levels?

The ideal future state for Product 1 would include a clear strategy for inventory that considers the current business characteristics and allows for strategy modification as the product environment changes (in other words, as the process returns to a stable state when the quality issues are resolved).

6.1.3 Product 1 Analysis

In order to achieve the desired future state for Product 1, the following product information must be considered and included as user inputs in the inventory model:

- Up to date and accurate demand forecasts,
- Knowledge of available future capacity,
- Understanding of the past process problems, and
- Emergency stock requirements.

Using Step 1 of the model, the key business characteristics of the product were analyzed. It was determined that the following attributes were necessary for the strategy and were incorporated into the information input into Step 1:

- Since Product 1 is a life saving product, it is necessary to carry some levels of Semi-Finished and Finished Goods strategic stock that can quickly be converted into the required country packaging and delivered in an emergency.

- Inventory cannot be carried at the bulk process stage due to product stability.
- A new facility being built in Marburg could disrupt the concentrate manufacturing process, which drives the need for strategic stock at that stage.
- The shelf life is high at 4 years, which allows carrying extra stock with low risk, despite the customer's preference for stock with over 1 year until the expiration data.

The input of these factors resulted in the strategy for Product 1 as shown in Figure 12.

Recommended Stages and Types of Inventory to Hold

	Concentrate	Bulk	Semi-Finished	Finished Goods
Work in Process Inventory	Yes	Yes	Yes	Yes
Cycle Inventory	No	No	No	Yes
Safety Inventory	Yes	No	Yes	Yes
Strategic Inventory	Yes	No	Yes	Yes

Figure 12: Recommended Inventory Strategy for Product 1

Next, these results were used to perform the second step of the inventory model analysis. For step 2, it was determined that no changes would be made to the standard information related to Lead Times or Capacity. However, it was desired that there be at least one year of strategic stock spread across the concentrate, semi-finished and finished goods stages.

Step 2 of the model was first run using a strategic stock level of one year worth of demand which lead to the results shown in Table 8.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base*	Safety	Strategic	Total
Concentrate	152,136	58,560	415,953	626,649
Bulk	25,641	0	0	25,641
Semi-Finished	146,299	56,511	415,953	618,763
Finished Goods	190,902	56,081	415,953	662,936
Total	514,979	171,151	1,247,859	1,933,988

Table 8: Product 1 Results, 1 Year Strategic Inventory

* Base Stock is equal to WIP stock + Cycle Stock for the given process stage.

Since the results yielded very high numbers, it was necessary to re-run the model using 6 months of demand for strategic inventory. These results were more reasonable (shown in Table 9), yet still a bit high at approximately 620,000 doses on hand as strategic inventory and a total of 1.3 million doses on average in any given month.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total
Concentrate	152,136	58,560	207,976	418,673
Bulk	25,641	0	0	25,641
Semi-Finished	146,299	56,511	207,976	410,786
Finished Goods	190,902	56,081	207,976	454,959
Total	514,979	171,151	623,929	1,310,059

Table 9: Product 1 Result, 6 Months Strategic Inventory

Using these numbers, discussion began about their reasonableness and the assumptions that were used in the model. Factors that were considered when evaluating the results were:

- Cost tradeoffs associated with carrying excess product versus losing sales
- The likelihood of exceeding the current demand
- Political impacts that might drive inventory level decisions
- Risk to the market share if the product is not able to be sold
- Actual need for emergency stock
    - In Marburg, only 3,500 doses are allocated as emergency stock and during the month of August 2009, only 3 emergency orders were placed of quantities of 6, 30 and 85 doses

After considering all of the factors, although the values that resulted with the six month assumption were higher than expected, it was still at a level that seemed appropriate. As a result, the best option is to build extra stock today at the six month level. This will provide protection against uncertain performance as well as known future production risks, which is very important, based on the recent challenges delivering the product to customers.

6.2 Product 2 Case Study: Responding to Unexpected Demand Changes

The second product analyzed using the inventory model is also manufactured at the Marburg, Germany site. For Product 2, the current forecasted demand for 2010 is approximately 3.8 million doses split between two different dosages and is primarily delivered to European countries.

6.2.1 Product 2 Current State

Product 2 currently has inventory levels that are in excess of the projected demand for 2010. In 2009, Production Logistics executed to a production plan with high demand projections that had come from Commercial Supply Chain; however, not only did the forecasted demands decrease gradually in 2009, but even the lowered numbers were not achieved.

This lead to carrying much higher amounts of inventory than demand requires and the risk that this material will become obsolete if the demand remains at the current low level that is forecasted.

6.2.2 Product 2 Problem Statement

Although it is not possible to change the decisions made in the past, the question posed is how a formal inventory management process or tool could help in scenarios such as this, when demand forecasts change drastically.

The desired future state for Product 2 is to have a confident demand projection from the Rolling Forecast, to be able to use market intelligence to evaluate reasonability of the demand projections and, most importantly, to have a tool that allows management to see immediately how each new demand forecast impacts the projected inventory levels.

With the new inventory management policy this can be achieved by using the inventory model to develop targets in unison with the budgeting process, including monthly reviews of the projections when each new Rolling Forecast is released to identify changes early enough to make manufacturing planning changes.

6.2.3 Product 2 Analysis

In order to test the reasonableness of the assumption that the model could help with responding to large demand changes, a What-If scenario was performed using the 2009 data. The What-If scenario evaluated how the inventory targets would have changed over the period if the tool were in place.

To be consistent with the inventory management process put in place, the first step in performing the scenarios was to complete the evaluation of the business characteristics of the product before performing the iterative analytical model results. The key characteristics that play into Product 2's inventory management strategy are:

- Strategic inventory was not necessary at any manufacturing stage due to the extra amounts of inventory that already exist beyond the forecasted demand.
- The past high demand variability made it critical to carry safety stock to protect against future fluctuations
- No additional inventory beyond Work In Process stock could be carried at the Bulk stage due to process stability

This resulted in the inventory strategy shown in Figure 13 for Product 2:

Recommended Stages and Types of Inventory to Hold

	Concentrate	Bulk	Semi-Finished	Finished Goods
Work In Process Invento	Yes	Yes	Yes	Yes
Cycle Inventory	No	No	No	Yes
Safety Inventory	Yes	No	Yes	Yes
Strategic Inventory	No	No	No	No

Figure 13: Recommended Inventory Strategy for Product 2

This information fed into step 2 of the model, where the analytical calculations are performed to determine the target inventory levels. For the purpose of the analytical model, no modifications were made to the standard lead times for Product 2; however, some changes were made to the capacity constraints, which affect how inventory is spread across the months, but not the average inventory levels.

For this What-If analysis, the most critical input is the 18 month rolling forecast data which can be used to run the model repeatedly after updating it with each month's

forecast from January 2009 to July 2009. Figure 14 is a chart that shows how the monthly demand forecasts changed between the months of January, April and July 2009. From the chart it can be seen that as early as April, the demand forecasts for some months (June and July) were being greatly reduced. In July, it can be seen that the reductions were carried forward into the first half of 2010.

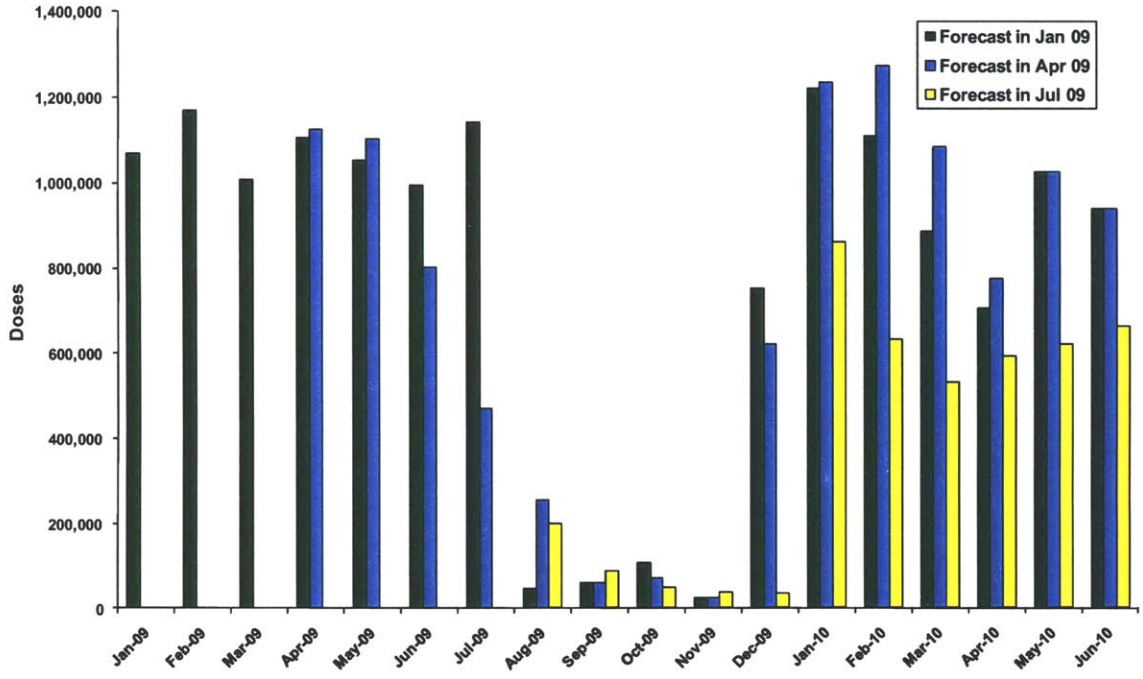

Figure 14: Monthly Rolling Forecast for Product 2

As is expected, the results from the inventory model follow the demand forecast changes for Product 2 and reduce over time. If we isolate the month of July, Table 10 shows how management could have been alerted to a large change in the needed inventory as early as March when inventory targets reduced by nearly five million doses.

Month Target Was Set In	Target For Jul-09
Jan 09	11,849,956
Feb 09	11,826,049
Mar 09	6,861,071
Apr 09	7,091,481
May 09	6,695,047

Jun 09	5,627,778

Table 10: Product 2 Inventory Target Changes for July 2009

Additionally, by combining the inventory target data with actual inventory on hand data, it is possible to see the differences between what is required to meet customer demand and the actual inventory on hand for a given month. Figure 15 shows the inventory on hand level compared to the inventory targets based on the January 2009 RFC versus the July 2009 RFC. It is clear from this figure that inventory levels were achieved based on the original forecasts; however, they are far off from the changes that occurred over the months between the January forecast and the actual month of July.

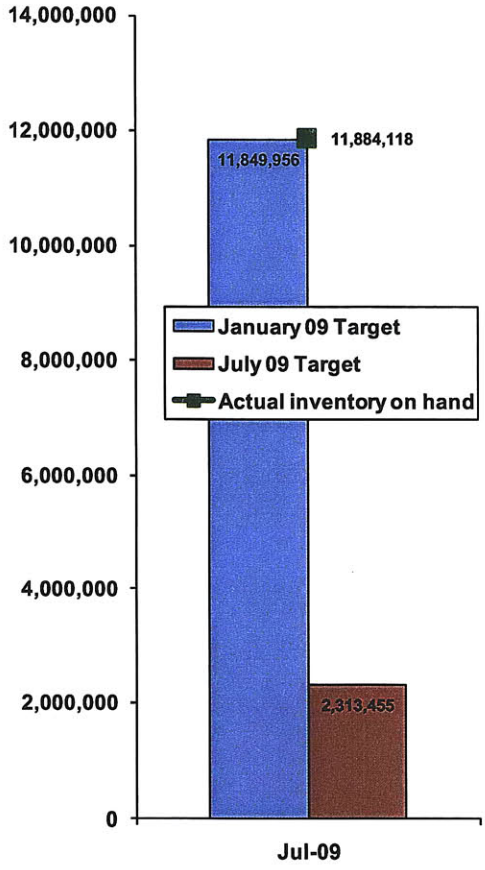

Figure 15: July Inventory On Hang versus Targets

As a result of this analysis, it is clear that having the ability to forecast inventory targets as well as update the targets when demands change, could have helped solve the problems that occurred with the supply planning for Product 2.

6.3 Case Study: Product 3, Using What-If Scenarios to Prepare for the Future

The third product that was evaluated using the new inventory management process, Product 3, is manufactured, filled and packaged in Rosia, Italy. The vaccine is distributed all across the world and as of December 2009, just over 13 million doses are forecasted for the entire world market during 2010 and the first six months of 2011.

6.3.1 Product 3 Current State

The current inventory levels for Product 3 are at a healthy state based on the demand and supply activity during 2009; however, in the next 18 months, Product 3 will be facing very high uncertainty with both demand and supply forecasts.

Although Product 3 has a forecast in place for the next 18 months, this demand forecast is highly uncertain due to the possibility of Novartis being able to enter the market of one country in South America for this vaccine. The additional demand for this market could be either 50,000 or 800,000 doses per month for the product's life. The current forecast assumes that the upside is achieved, but only through the end of 2010.

In addition to the demand uncertainty, there is also a level of uncertainty related to supply. This is due to the fact that the contract for a major supplier will be ending and not renewed in 2010. Although alternative suppliers have been identified, it is uncertain if they will be qualified and fully up to speed by the time the contract ends. This means that the total available manufacturing capacity for this vaccine could be a lot less than in past years.

6.3.2 Product 3 Problem Statement

With this uncertainty for both supply and demand, management needs to answer two questions:

1. What inventory levels are needed to satisfy both the downside and upside of the potential future demand for the South American country?
2. How can the potential supply risk be managed to ensure that demand can be met until a new supplier is onboard?

6.3.3 Product 3 Analysis

Using the inventory model, these questions can be answered by performing What-If scenarios based on the different possible outcomes. Based on what could occur there are four outcomes identified that needed to be evaluated, as shown in Figure 16. These four scenarios along with the base scenario were evaluated in order to help management understand the different potential outcomes.

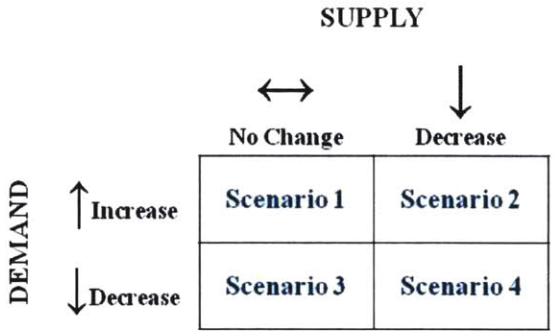

Figure 16: Product 3 Demand & Supply Scenarios

Before the detailed analytical calculations could be performed; however, the business characteristics had to be evaluated. For Product 3, the following product characteristics were used to complete this step of the inventory analysis:

- No extra bulk inventory carried due to short shelf life during this process stage
- No extra finished goods inventory is carried because the product packaging is country specific and does not allow for flexibility if order quantities or destinations change
- Strategic inventory (when needed) is only carried at the concentrate and the semi-finished good stages

This resulted in the inventory management strategy shown in Figure 17.

Recommended Stages and Types of Inventory to Hold

	Concentrate	Bulk	Semi-Finished	Finished Goods
Work in Process Inventory	Yes	Yes	Yes	Yes
Cycle Inventory	No	No	Yes	No
Safety Inventory	Yes	No	Yes	No
Strategic Inventory	Yes	No	Yes	No

Figure 17: Recommended Inventory Strategy for Product 3

With this inventory strategy defined, the analytical details could be input to begin the detailed analysis. In order to perform the What-If scenarios as described, the two attributes that need to be changed are the demand forecast numbers for the next 18 months and the amount of extra strategic inventory required to ensure that demand during the months when supply is short is met. In order to perform this analysis, five scenarios were run:

- Baseline scenario (Table 11): Demand forecast numbers come directly from the December 2009 rolling forecast and there is no strategic inventory required due to supply availability risk.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total	# of Batches	Days of Coverage
Concentrate	2,038,345	28,200	0	2,066,545	1.3	82.1
Bulk	188,736	0	0	188,736	0.1	7.5
Semi-Finished	1,308,567	19,059	0	1,327,626	17.7	52.8
Finished Goods	75,494	0	0	75,494	1.0	3.0
Total	3,611,142	47,259	0	3,658,401	20.1	145.4

Table 11: Product 4 Inventory Targets – Baseline

- Scenario 1 - Upside scenario with no supply issues (Table 12): The 18 month rolling forecast demand is increased to assume that the new country requests 800,000 doses per month and there is no strategic inventory required due to supply availability risk.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total	# of Batches	Days of Coverage
Concentrate	2,638,345	28,200	0	2,666,545	1.7	81.9
Bulk	244,291	0	0	244,291	0.2	7.5
Semi-Finished	1,693,752	19,059	0	1,712,812	22.8	52.6
Finished Goods	97,716	0	0	97,716	1.3	3.0
Total	4,674,105	47,259	0	4,721,364	26.0	145.0

Table 12: Product 4 Inventory Targets - Upside

- Scenario 2 - Upside scenario with supply issues (Table 13): The 18 month rolling forecast demand is increased to assume that the new country requests 800,000

doses per month. Supply constraints begin in 2011; 6 months of strategic inventory is required to protect during anticipated gap in supply.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total	# of Batches	Days of Coverage
Concentrate	2,638,345	28,200	5,862,989	8,529,534	5.3	261.9
Bulk	244,291	0	0	244,291	0.2	7.5
Semi-Finished	1,693,752	19,059	5,862,989	7,575,801	101.0	232.6
Finished Goods	97,716	0	0	97,716	1.3	3.0
Total	4,674,105	47,259	11,725,979	16,447,343	107.8	505.0

Table 13: Product 4 Inventory Targets – Upside & Supply Risk

- Scenario 3 - Downside scenario with no supply issues (Table 14): The 18 month rolling forecast demand is modified to assume that the new country requests 50,000 doses per month and there is no strategic inventory required due to supply availability risk.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total	# of Batches	Days of Coverage
Concentrate	1,400,845	28,200	0	1,429,045	0.9	82.6
Bulk	129,708	0	0	129,708	0.1	7.5
Semi-Finished	899,308	19,059	0	918,367	12.2	53.1
Finished Goods	51,883	0	0	51,883	0.7	3.0
Total	2,481,744	47,259	0	2,529,003	13.9	146.2

Table 14: Product 4 Inventory Targets - Downside

- Scenario 4 - Downside scenario with supply issues (Table 15): The 18 month rolling forecast demand is modified to assume that the new country requests 50,000 doses per month. Supply constraints begin in 2011; 6 months of strategic inventory is required to protect during anticipated gap in supply.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total	# of Batches	Days of Coverage
Concentrate	1,400,845	28,200	3,112,989	4,542,034	2.8	262.6
Bulk	129,708	0	0	129,708	0.1	7.5
Semi-Finished	899,308	19,059	3,112,989	4,031,356	53.8	233.1
Finished Goods	51,883	0	0	51,883	0.7	3.0
Total	2,481,744	47,259	6,225,979	8,754,982	57.4	506.2

Table 15: Product 4 Inventory Targets – Downside & Supply Risk

These results provide insight into how the inventory targets fluctuate based on the added demand as well as how adding strategic inventory to the plan can help protect against future risk and impact the inventory targets.

The final step in evaluating the inventory plan for Product 3 involved looking at the 5 scenarios side-by-side and considering the key factors to determine which scenario makes more sense to move forward. Management is able to consider factors such as the likelihood that the high side demand is really achieved and whether or not the new supplier will be able to be qualified before the contract for the old supplier ends. In the end, with high confidence that the demand of 800,000 doses per month would be achieved and low confidence the new supplier would be onboard in time Scenario 2 – Upside and Supply Risk was the ideal inventory target plan for 2010.

6.4 Chapter Summary

Throughout this Chapter, we have seen how this inventory model can be applied to a variety of products with varying challenges. The model has been able to help us answer questions not only about using the model to set inventory targets, but also allows us to use the model to run different scenarios when the future is uncertain or there are different values that may need to be evaluated for a single variable.

7 Conclusions

The previous Chapters in this thesis have explored the environment of an organization that has high customer service requirements, a very diverse product portfolio and is still in the early stages of defining business processes. The uniqueness of the current business environment at Novartis is explored and it was explained how an inventory model was built to allow for customization and flexibility to fit their environment. Using three critical products, the model was tested to show that it could be integrated into the Sales & Operations Planning process and produce usable results. Finally, a formal policy was put in place to guide the use of the model and to ensure a process for change control when inventory targets need to be modified. These activities lead to the successful implementation of not just a tool but a process that can be used to more effectively manage product inventory.

7.1 Opportunities for Further Research and Process Development

Novartis Vaccines already has a strong Global Supply Chain group that is striving to put policies in place that support the roles of the people in the organization. Setting up the inventory management policy is just one step in the right direction. Below are three areas that need to be focused on to not only offer continuous improvement of the new inventory management process but also to help future process improvement and implementation activities.

Further development of the demand forecasting process is necessary. Having a more robust demand forecasting process and a better way to measure forecast accuracy would not only help improve the usefulness of the inventory model, but would also help improve cohesiveness across the supply chain organization. The current process relies heavily on the knowledge of the commercial sales representatives and allows subjectivity that causes the Production Logistics personnel to have high levels of doubt in the forecasts they receive. By implementing a mathematical or statistical method for demand forecasts, the process could be greatly improved.

Implementing a method to track and monitor planned and actual lead times throughout all stages of the manufacturing process (including transportation) would help

the organization have a better grasp on where problems are occurring in the process and where true opportunities for improvement exist. Value Stream Maps* are beginning to be fully utilized within the Supply Chain group at Novartis Vaccines and these types of tools are most successful when there is accurate data (including a significant amount of history) to help evaluate the opportunities for savings.

Finally, Novartis Vaccines would benefit greatly from setting up more formal process around the use of SAP as well as maintaining the integrity of the data in SAP. There are many types of information that are currently tracked manually in Excel spreadsheets that could be maintained by the system. In order to get the most out of SAP's functionality, the time and effort needs to be made to set it up properly. Ultimately, it will save a lot more recurring time for supply chain personnel than is needed for the initial set up.

7.2 Summary of Findings & Recommendations

Based on the lessons learned during the development of this inventory management policy, there are three key findings that any organization in a similar position must remember in order to successfully implement an inventory policy:

- Balance analytical considerations with business sense; neither aspect is more or less important than the other. When setting policies and strategies it is important that all factors of the business are considered.
- Select the level of data aggregation carefully to ensure consideration of product specific characteristics yet avoid unnecessary complexity. Each stakeholder is likely to have a different opinion about what level of data is needed; however, factors such as the availability of the current data and how performance is currently measured in the organization must be considered. If a level of detail is selected that does not fit with the business structure, the tool will not be useful.

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* Value Stream Maps are a tool to help see and understand the flow of product and material through the value stream (Rother & Shook, 2003). They are used to help identify waste within the process and develop improvement ideas to help increase the overall efficiency of the analyzed process.

- Creating an analytical model or business process does not solve the entire problem related to inventory management. There are many "soft" factors that need to be considered. Implementations must not happen in a silo and organizations should not only be aware of the changes, but also have the ability to provide input in ensuring their success.

In conclusion, it has been shown that the combination of a dynamic model, product business knowledge and formal processes leads to an inventory policy that not only provides inventory targets that an organization believes in, but also a process that the entire team supports.

Appendix 1: Inventory Model Step 1 Input Sheet

Evaluation of Inventory Types and Stages Based on Business Characteristics

Product Name:

Please select use Yes or No to indicate which process stages are required for this product and where Work in Process (WIP) inventory will exist.

Concentrate	No
Bulk	No
Semi-Finished	No
Finished Goods	No

Can you hold extra inventory (above WIP) at each of the following process stages?

Concentrate	No
Bulk	No
Semi-Finished	No
Finished Goods	No

Which stage should cycle inventory be carried to protect for demand during the cycle period?

Concentrate	No
Bulk	No
Semi-Finished	No
Finished Goods	No

Is the product critical or life savings?	No
	No
	No
	No
	No
	No
Is there a known future manufacturing interruption?	No
	No
	No
	No
	No
	No
Is a large amount of demand expected during a time when capacity is limited?	No
	No
	No
	No
	No
	No
Are any of the processes currently very unstable or unpredictable?	No
	No
	No
	No
	No
	No

Appendix 2: Inventory Model Step 2 Input Sheet

Inventory Management Analytical Model

For all boxes colored yellow, please fill in the appropriate information for that box.

Click Here Restore to Default Values

Sub Group

Please select the customer service level that you would like to meet: 98.0%

Inventory Carrying Strategy, based on the results from Step 1. A 1 indicates inventory is carried for that type of material at the given stage, a 0 indicates inventory is not carried at that location.

	Concentrate	Bulk	Semi-Finished	Finished Goods
Work in Process Inventory	1	1	0	0
Cycle Inventory	1	0	0	0
Safety Inventory	1	1	0	0
Strategic Inventory	1	0	0	0

Please indicate the duration of the frozen period for demand forecasts. If you would like to use no frozen period for this scenario, please input 0.

90 *days (assume 30 days per month)*

Please indicate the frequency of order replenishment at each process stage. The frequency should be the number of times a month an order/batch can run at that material stage.

Concentrate	7	*orders/batches that can be run per month*
Bulk	0	*orders/batches that can be run per month*
Semi-Finished	0	*orders/batches that can be run per month*
Finished Goods	0	*orders/batches that can be run per month*

If you would like to make modifications to the capacity plan for the next 18 months, click the "+" sign on the left side, otherwise, move on to the next section.

Please use the table below to indicate how annual demand can be filled throughout the year.

A "1" indicates that monthly demand can be filled as planned, a value less than "1" would indicate there is less capacity than needed and a value greater than "1" would indicate there is more capacity than needed for that months demand. The Total column should always equal 18, but can be distributed however is appropriate across the months.

	DEC 2009	JAN 2010	FEB 2010	MAR 2010	APR 2010	MAY 2010	JUN 2010	JUL 2010	AUG 2010	SEP 2010	OCT 2010	NOV 2010	DEC 2010	JAN 2011	FEB 2011	MAR 2011	APR
Concentrate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	10
Bulk	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	10
Semi-Finished	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	10
Finished Goods	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	10

The model will use fixed lead times based on normal operations. Please indicate whether you would like to modify the lead times and input the new lead time for that stage.

Concentrate Material

Standard Lead Time		days
Do you want to change the lead time for this material?	N	
If yes, please enter the new lead time in days.	0.0	days

Bulk Material

Standard Lead Time		days
Do you want to change the lead time for this material?	N	
If yes, please enter the new lead time in days.	0.0	days

Semi-Finished

Standard Lead Time		days
Do you want to change the lead time for this material?	N	
If yes, please enter the new lead time in days.	0.0	days

Finished Goods

Standard Lead Time		days
Do you want to change the lead time for this material?	N	
If yes, please enter the new lead time in days.	0.0	days

For inventory types that will carry strategic inventory, please input the amount of coverage (in days) that will be necessary to support this area:
If strategic inventory will not be carried, please ensure all values for that material type are 0.

TYPE	DEC 2009	JAN 2010	FEB 2010	MAR 2010	APR 2010	MAY 2010	JUN 2010	JUL 2010	AUG 2010	SEP 2010	OCT 2010	NOV 2010	DEC 2010	JAN 2011	FEB 2011	MAR 2011	APR
Concentrate	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	18
Bulk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Semi-Finished	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finished Goods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3: Inventory Model Step 2 Output Sheet

Inventory Targets Analytical Model Results
Product Sub Group: Product 1234
Demand during 18 month RFC Period: 124,226,509

Error Messages
Capacity
Shelf Life Material is at risk due to Shelf Life limitations.

Average Monthly Inventory Levels for 18 Month RFC

values are in doses	Base	Safety	Strategic	Total	# of Batches	Days of Coverage
Concentrate	17,779,508	4,084,630	41,408,836	63,272,975	19.2	275.0
Bulk	10,352,209	3,471,880	0	13,824,089	4.2	60.1
Semi-Finished	0	0	0	0	0.0	0.0
Finished Goods	0	0	0	0	0.0	0.0
Total	28,131,717	7,556,510	41,408,836	77,097,064	23.4	335.1

Strategic Inventory for 18 Month RFC

	DEC 2009	JAN 2010	FEB 2010	MAR 2010	APR 2010	MAY 2010	JUN 2010	JUL 2010	AUG 2010	SEP 2010	OCT 2010	NOV 2010	DEC 2010	JAN 2011	FEB 201
Concentrate	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,836	41,408,83
Bulk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Semi-Finished	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finished Goods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total Monthly Inventory Targets

	DEC 2009	JAN 2010	FEB 2010	MAR 2010	APR 2010	MAY 2010	JUN 2010	JUL 2010	AUG 2010	SEP 2010	OCT 2010	NOV 2010	DEC 2010	JAN 2011	FEB 201
Total Inventory	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,064	77,097,06

Shelf Life Validation

	DEC 2009	JAN 2010	FEB 2010	MAR 2010	APR 2010	MAY 2010	JUN 2010	JUL 2010	AUG 2010	SEP 2010	OCT 2010	NOV 2010	DEC 2010	JAN 2011	FEB 201
	Ok	Ok	Ok	Ok	Ok	Ok	Ok	At Risk	At Risk	Ok	Ok	Ok	Ok	At Risk	Ok
Concentrate	0	0	0	0	0	0	0	16,710,578	41,208,704	0	0	0	0	39,066,323	0
Bulk	0	0	0	0	0	0	0	1,456,630	3,171,880	0	0	0	0	3,021,880	0
Semi-Finished	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Finished Goods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Average Monthly Inventory Costs

Euros	Base + Safety	Strategic	Total
Concentrate	31,636,487	20,704,418	52,340,905
Bulk	27,648,179	0	27,648,179
Semi-Finished	0	0	0
Finished Goods	0	0	0
Monthly Costs	59,284,666	20,704,418	79,989,084

Appendix 4: Sensitivity Analysis Details

Testing the sensitivity of Customer Service Level

Original Value	98%				
	Base	Safety	Strategic	Total	
Concentrate	1,742,502	920,517	3,872,226	6,535,245	
Bulk	161,343	0	0	161,343	
Semi-Finished	882,007	521,526	3,872,226	5,275,759	
Finished Goods	64,537	0	0	64,537	
Total	2,850,389	1,442,044	7,744,452	12,036,884	
Modified Value	99%				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,742,502	1,042,700	3,872,226	6,657,427	1.9%
Bulk	161,343	0	0	161,343	0.0%
Semi-Finished	882,007	590,750	3,872,226	5,344,983	1.3%
Finished Goods	64,537	0	0	64,537	0.0%
Total	2,850,389	1,633,449	7,744,452	12,228,290	1.6%
Modified Value	99.5				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,742,502	1,154,521	3,872,226	6,769,248	1.7%
Bulk	161,343	0	0	161,343	0.0%
Semi-Finished	882,007	654,103	3,872,226	5,408,336	1.2%
Finished Goods	64,537	0	0	64,537	0.0%
Total	2,850,389	1,808,623	7,744,452	12,403,464	1.4%
Modified Value	96%				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,742,502	784,681	3,872,226	6,399,408	-2.1%
Bulk	161,343	0	0	161,343	0.0%
Semi-Finished	882,007	444,567	3,872,226	5,198,800	-1.5%
Finished Goods	64,537	0	0	64,537	0.0%
Total	2,850,389	1,229,247	7,744,452	11,824,088	-1.8%

Testing the Sensitivity of the Frozen Period

Original Value	15 days				
	Base	Safety	Strategic	Total	
Concentrate	1,742,502	920,517	3,872,226	6,535,245	
Bulk	161,343	0	0	161,343	
Semi-Finished	882,007	521,526	3,872,226	5,275,759	
Finished Goods	64,537	0	0	64,537	
Total	2,850,389	1,442,044	7,744,452	12,036,884	
Modified Value	90 days				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,742,502	920,517	3,872,226	6,535,245	0.0%
Bulk	968,057	0	0	968,057	500.0%
Semi-Finished	882,007	521,526	3,872,226	5,275,759	0.0%
Finished Goods	64,537	0	0	64,537	0.0%
Total	3,657,102	1,442,044	7,744,452	12,843,598	6.7%
Modified Value	30 days				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,742,502	920,517	3,872,226	6,535,245	0.0%
Bulk	322,686	0	0	322,686	100.0%
Semi-Finished	882,007	521,526	3,872,226	5,275,759	0.0%
Finished Goods	64,537	0	0	64,537	0.0%
Total	3,011,731	1,442,044	7,744,452	12,198,227	1.3%

Testing the Sensitivity of Order Replenishment

Original Value	all at 1 per month				
	Base	Safety	Strategic	Total	
Concentrate	1,742,502	920,517	3,872,226	6,535,245	
Bulk	645,371	0	0	645,371	
Semi-Finished	1,462,841	744,607	3,872,226	6,079,674	
Finished Goods	645,371	0	0	645,371	
Total	4,496,085	1,665,125	7,744,452	13,905,661	
Modified Value	all at 4 times per month				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,258,473	782,289	3,872,226	5,912,989	-9.5%
Bulk	161,343	0	0	161,343	-75.0%
Semi-Finished	978,813	564,858	3,872,226	5,415,897	-10.9%
Finished Goods	161,343	0	0	161,343	-75.0%
Total	2,559,972	1,347,147	7,744,452	11,651,571	-16.2%
Modified Value	all at 10 times per month				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,161,668	751,599	3,872,226	5,785,493	-11.5%
Bulk	161,343	0	0	161,343	-75.0%
Semi-Finished	882,007	521,526	3,872,226	5,275,759	-13.2%
Finished Goods	64,537	0	0	64,537	-90.0%
Total	2,269,555	1,273,125	7,744,452	11,287,132	-18.8%
Modified Value	all at 30 times per month				
	Base	Safety	Strategic	Total	% Change
Concentrate	1,118,643	737,549	3,872,226	5,728,419	-12.3%
Bulk	161,343	0	0	161,343	-75.0%
Semi-Finished	838,982	501,066	3,872,226	5,212,274	-14.3%
Finished Goods	21,512	0	0	21,512	-96.7%
Total	2,140,480	1,238,616	7,744,452	11,123,548	-20.0%

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