# ASSEMBLE-TO-ORDER AND POSTPONEMENT STRATEGIES AT ABC WIRELESS INC.

**by**

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# EXECUTIVE SUMMARY

ABC Wireless has achieved tremendous success in the wireless telematics industry and in recent years has experienced dramatic growth in both sales and operations. As a result of this expansion, there is increased pressure on the supply chain, specifically on activities related to inventory management. Rising sales volumes, high variability in demand and proliferation of product variety has lead to a surge in supply chain complexity and uncertainty. As ABC's business has evolved, they have pursued a supply chain strategy focused on reducing manufacturing costs. While this strategy has allowed ABC to benefit from economies of scale, it has hindered their ability to manage or respond quickly to changing demand.

By evaluating various supply chain strategies, this analysis shows that ABC would benefit from refocusing their supply chain from one fixed on low-cost manufacturing to one designed to provide responsiveness. In particular, ABC's business seems aligned to an Assemble-to-Order strategy, whereby they are able to realize the benefits of economies of scale while remaining agile. By implementing this strategy, ABC would be able to reduce supply chain complexity and mitigate risk related to demand uncertainty.

There are several techniques for achieving Assemble-to-Order supply chains including sophisticated demand forecasting and redesigning product for modularity. However, the simplest and perhaps most effective strategy is a concept referred to as ‘postponement’.  Postponement uses delayed product differentiation to simplify supply chain processes while pooling demand for several products.

This analysis recommends that ABC Wireless implement postponement within their supply chain.  It is shown that postponement, achieved through process re-sequencing, reduces lead-times and lessens uncertainty, thus allowing for an overall reduction in inventory.  Using sales data from fiscal 2007 and 2008, it is shown that, when compared to ABC’s existing supply chain, postponement would eliminate two million dollars worth of in-transit inventory and close to six-hundred thousand dollars worth of safety stock.  Finally, while the primary benefit of postponement is costs savings associated with inventory management, additional benefits include reduced risk of product obsolescence and improved version control.

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# 1: OVERVIEW

## 1.1 Introduction

Within any company, success is greatly determined by a firm's ability to acquire resources, add value and deliver products or services to their customers. This basic capability is often called a supply chain or value chain and in recent years companies have begun to focus on increasing the efficiency and effectiveness of this process. Supply Chain Management has become a discipline unto itself and many strategies have emerged, each with their own advantages and disadvantages.

Supply chains encompass many responsibilities including purchasing, manufacturing, inventory management, and logistics. Ideally, these areas are closely integrated and information and goods flow seamlessly between functional units. Unfortunately, this is rarely the case, and the result of poor integration is inventory. (Bulgak, 2006) Inventory acts as a buffer, helping companies manage the inefficiencies and uncertainties present in every supply chain. For manufacturing companies, inventory plays an important part in the supply chain. As a result, much has been written on techniques and calculations to find optimal inventory levels and reorder quantities. Even with all these techniques, many firms have found that, despite their best efforts, their existing supply chain cannot meet the demands of customers within the constraints imposed upon them by their suppliers. Specifically, in recent years, customers have begun to demand highly customized products, at low cost, and they expect it immediately. This level of service was not possible using traditional manufacture to stock (MTS) or manufacture to plan (MTP) techniques. As such, firms have been forced to re-examine and reengineer their supply chains. Two strategies that have evolved to deal with demands of customers in highly ambiguous environments are assemble-to-order (ATO) and manufacture to order (MTO).

Within the technology industry, the pressure to deliver differentiated products at low cost has been intense. In order to minimize costs, firms have been forced to utilize low-cost manufacturing in countries such as India and China. At the same time, customers expect that once they place an order, they will receive product in a relatively short period of time. Companies such as Dell have been able to address these pressures by using ATO and MTO techniques.

For ABC Wireless Inc (ABC), a leading supplier of GPS tracking devices for fleet vehicles, these demands are all too real. There is strong pressure to compete on the price of hardware while offering customers a variety of customizable products. Meanwhile, customers continue to expect product shortly after placing an order. In an attempt to keep manufacturing costs down, ABC has looked to exploit low cost manufacturing overseas and, where possible, economies of scale. It has become apparent that ABC has been relying on traditional manufacture to stock strategies while trying to serve and compete in an environment that is more suited for responsive supply chains. This decision has forced ABC to carry excess inventory in order to meet uncertain demand, provide product variety and achieve economies of scale in manufacturing.

By adopting an assemble to order manufacturing strategy, ABC would be able to reduce inventory while gaining flexibility and responsiveness in their operations. This would be achieved while continuing to realize economies of scale in manufacturing and continuing to offer high product variety. The assemble to order manufacturing strategy is described in section 3.1.3.

## 1.2 Wireless Telematics Industry

Over the past 10-15 years the wireless telematics industry has grown in leaps and bounds as companies look for ways to track and monitor their high value assets. Improvements in technologies such as the Global Positioning System (GPS) and cellular data networks has meant that it has become possible for devices to be installed in vehicles to track and map the position of these assets in real time. In recent years this has become more popular as high fuel prices have brought an increased awareness and importance to fleet management. Wireless telematics is in its infancy and is characterized by a large number of relatively small competitors. In order to survive, firms have been forced to compete on price while offering products with a variety of features, often customizing or configuring products for specific customers.

## 1.3 ABC Wireless

### 1.3.1 Company Background

Founded in 1999 by Anwar Sukkarie and Cameron Fraser, ABC Wireless designs, manufactures and delivers GPS tracking devices and vehicle telematics solutions worldwide. With a focus on commercial fleets, both large and small, ABC uses GPS and the wireless GSM cellular network to provide real-time information and vehicle tracking over the Internet. ABC combines its Locator hardware with a software portal (Quadrant) to provide a full solution for fleet management.

Headquartered in Burnaby, British Columbia, ABC has seen tremendous growth over the past five years and in 2007 ranked 13th in the Deloitte Technology Fast 50. In the past four years, total locator sales have quadrupled and revenues have grown to 15.3 million dollars annually. ABC has manufacturing facilities in Vancouver, British Columbia and sales offices in the United Kingdom, Brazil and Middle East. ABC continues to be engaged in opportunities that if won, will continue to drive their dramatic growth. At present there are over 150 employees worldwide in the areas of R&D, sales, technical support and operations.

### 1.3.2 Product – GPS Locator

At the heart of ABC's telematics solution is their leading edge, 'WT' series of locators (the Locator). Currently ABC offers two families of locator, the 'WT5000' and 'WT6000' but is looking to replace both models with its new feature rich 'WT7000' locator by the end of the year. ABC's 'WT' series locators are devices roughly the size of a PDA, which contain an integrated GPS receiver, wireless data modem and ABC's mobile service enabling technologies.

In simple terms, the Locator determines its location by communicating with the network of Global Positioning Satellites and transmits this information via a cellular radio network (GSM) to ABC's Quadrant Network Operations Centre. Quadrant then translates these position records and extracts location data and information into the customer's web portal. Recent versions of ABC's locators have the ability to interface with a vehicle's on board diagnostics computers (OBDII or J-Bus) and transmit information on vehicle status and performance to dispatchers in real time.

As is common in many technology industries, the product life-cycle for ABC's locators is relatively short. ABC estimates that the life-cycle for any one family of product is 3 years. During this time the product may experience several changes, including revisions to its printed circuit assembly/board (PCA/PCB), a variety of modems and obviously configurations.

## 1.4 Market Demand

### 1.4.1 Customer Needs

ABC's customers are as diverse as their needs. ABC provides hardware and services to small commercial fleets of 1-10 vehicles but also serves enterprise customers who track thousands of vehicles daily. The heterogeneous nature of the market segments mean there is a tremendous variety in customer needs, price sensitivity and intended application. In order to fulfil the needs of the customers, ABC must offer products that compete on cost but also have the ability to be configured and customized to the intended application. Because many customers are extremely price sensitive, ABC has expanded its product line and begun offering Locators at different price points. For companies, choosing a telematics solution is not a simple proposition. The capital costs associated with equipping the company's fleet with locators can be daunting and ROI uncertain. As such, customers have a high involvement in the purchase decision and are adamant that the product be tailored to meet their needs. By offering variety, ABC is able to satisfy these needs but also run the risk of information overload especially if they are intending to move towards 'self configured' locators. The traditionally long sales cycle of 100+ days supports this conclusion that ABC products and solutions are highly complex and require close collaboration between sale representatives from ABC and customers to determine the most appropriate solution. While this lengthy, high-involvement sales cycle can be perceived as a negative, it also means that ABC has good visibility to opportunities within their sales pipeline.

### 1.4.2 Supplier Needs

As a manufacturing company, ABC has close relationships to many of its suppliers. In order to reduce costs, ABC uses contract manufacturers (CM) to supply its printed circuit boards and Locator housings. By using CMs, ABC is able to capitalize on low-cost labour markets, specifically in China. The downside of using CMs is that in order for ABC to achieve the cost benefits, CMs require production runs of several thousand units. Other major component vendors are Motorola, who provide wireless modems and SiRF Technologies who supply GPS chipsets. Both components are attached to the PCA produced by the CM, the SiRF chips in the first production run and the modems attached in a second run. As a relatively small player in the wireless industry (competing with cellular handsets), ABC has little purchasing power with suppliers. While ABC recently negotiated with Motorola to ship modems directly from Motorola's factory in Israel to the CM in China, ABC has found it difficult to acheive improved production terms or responsiveness from suppliers. It will continue to be difficult for ABC to exert much pressure until production volumes increase.

## 1.5 Operational Goals

ABC is looking to achieve improved performance from their supply chain in several areas related to inventory management, responsiveness, customer service and scalability. Management recognizes that it may not be possible to achieve results in all areas and that improvements in one aspect may be at the expense of others.  Areas for supply chain improvement include

- reduced chance of stock outs
- improved accuracy of BOM
- improved inventory management (tracking)
- improved inventory planning and control
- agility and responsiveness
- reduced inventory

# 2: ANALYSIS OF CURRENT SITUATION AND ISSUES

## 2.1 Introduction

In order to cope with the tremendous growth over the past five years, ABC has needed to adapt their supply chain to meet the demands placed on it. Over time, the scope and scale of opportunities has increased and as a result, some aspects of ABC's supply chain operations have been stressed. ABC strives to remain cost competitive while continually improving the quality, performance and variety of product offered.

Increasing sales volume, variety and variation all have the effect of introducing uncertainty and complexity into the supply chain. Processes developed at the inception of the company were not designed to handle these factors and as a result supply chain performance has suffered. As is common in most high-growth companies, ABC reacted by focusing on demand forecasts (generated by their sales team) and by boosting inventory on-hand in the warehouse and as work-in-progress (WIP) (Muzumdar et al., 2003). These are both valid tactics for dealing with uncertainty and complexity in the system but they are by no means optimal, especially within a high-technology industry.

ABC has continued to experience pains in its supply chain, specifically Planning and Control and Inventory Management. ABC is looking for more effective and efficient methodologies to deal with increasing complexity and uncertainty resulting from market changes. This analysis will examine the factors driving ambiguity (volume, variability and variety) and identify areas of concern within ABC's Inventory Management and Planning and Control activities.

## 2.2 Manufacturing

In many respects, ABC takes a hybrid approach to manufacturing. ABC uses contract manufacturers in China to achieve lower production costs. These CMs take components as inputs and produce a finished ‘basic’ locator that consists of the printed circuit assembly (PCA), modem and housing. The inputs for the CMs are components that are purchased and supplied by ABC, mainly modems purchased from Motorola and GPS chips purchased from SiRF Technologies, but also smaller electronic components that are sourced and purchased by the CMs.

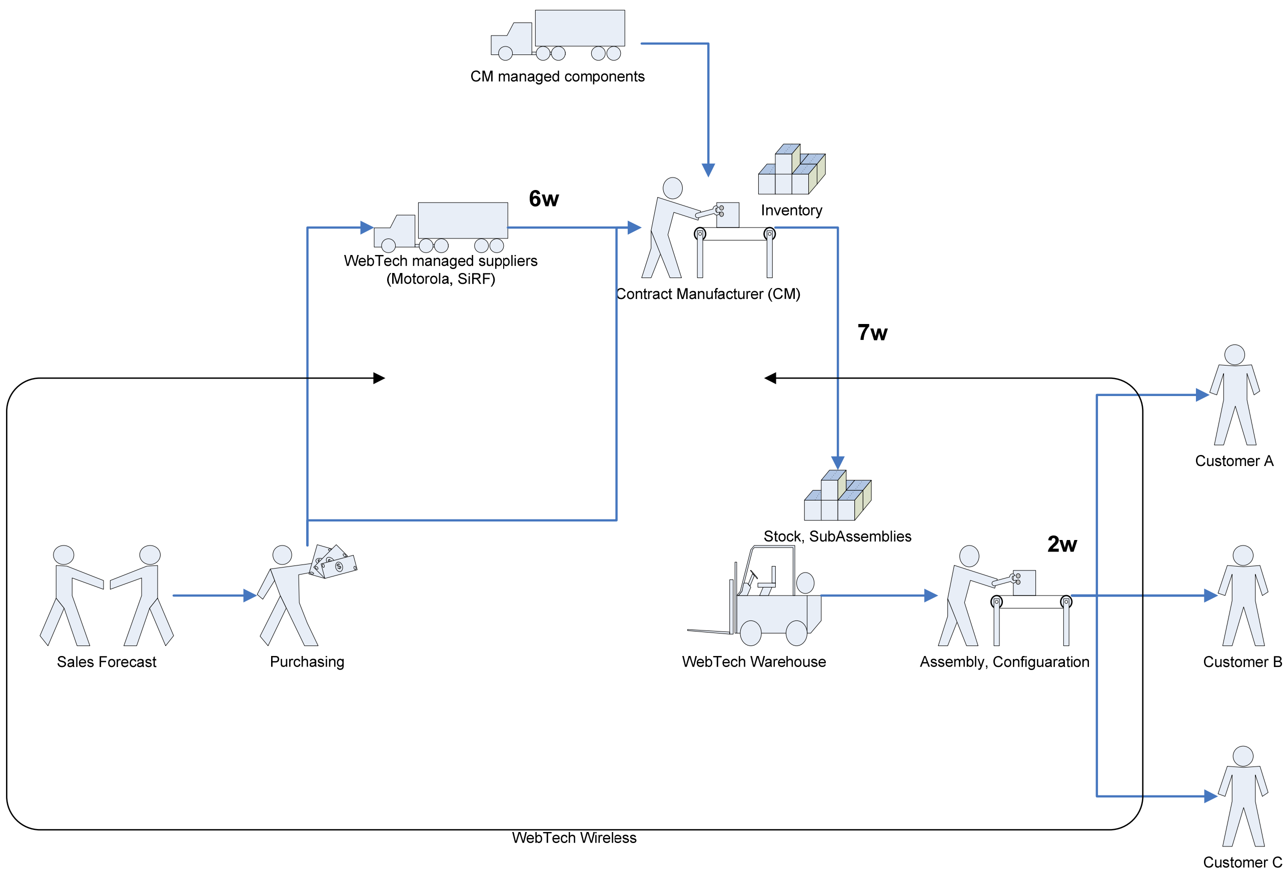
Once the CM has the components in stock, they require two production runs to manufacture the finished locator. The first production run consists of creating the PCB and attaching the GPS chips to the board. Because the costs to setup the manufacturing facilities are quite high, CMs discount large volume production runs in order to reduce their marginal costs. Included in this phase of manufacturing is moulding of the plastic housing, PCA including GPS chips and tooling costs. At the end of the first phase of production, the locator is in a generic form. It is only in the second production run that the locator begins to gain the components that determine its variety. The second production run attaches wireless modems to the PCA and appropriate labels (specific to the modem variety and destination) are affixed. After this point, the locator is in its basic form.

Locators are then shipped from the CMs to ABC’s warehouses via ocean transport. While this mode of transportation is cost effective, on average it take 7 weeks to deliver versus a few days when shipped by air. Ocean transport is essential to keep costs low as production volumes increase. Once the basic units have been received in

ABC's Canadian warehouse, they are stocked until demand is realized.  Once an order has been placed, the locators' final assembly takes place, including the antennas, back plate and software configuration.

Below is a basic diagram of the current manufacturing process for ABC locators. Lead-times (denoted in weeks) are represented by the XXw values.

**Figure 1: ABC Supply Chain**




The typical cost breakdown for a 'WT5000', 'WT6000' and 'WT7000' series locator are as follows:

**Table 1: Locator Unit Costs**

| | WT5000 | WT6000 | WT7000 |
|---|---|---|---|
| PCA and Plastics (includes SiRF chips) | $106 | $185 | $191 |
| Modem (variable $79-$113) | $113 | $113 | $113 |
| Cellular Antenna | $9 | $9 | $9 |
| GPS Antenna | $27 | $27 | $27 |
| Power Cable | $9 | $11 | $9 |
| Total | $264 | $345 | $349 |

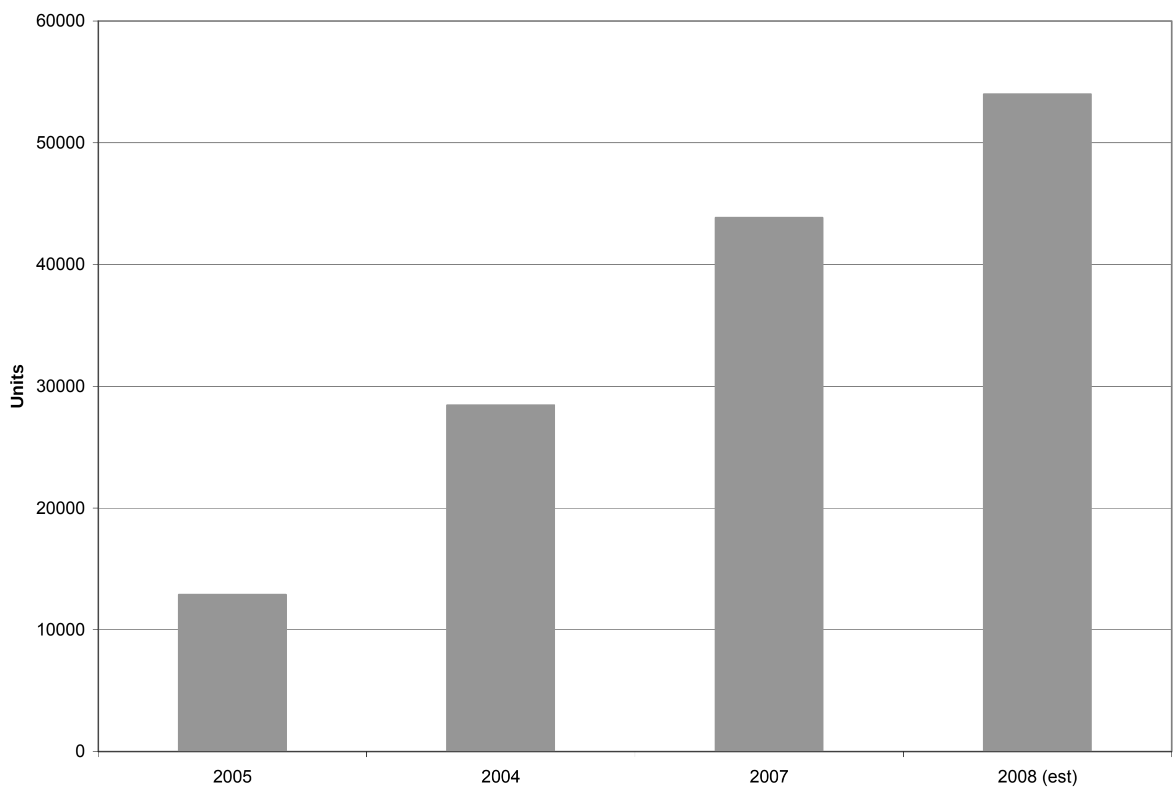
## 2.3 Uncertainty and Complexity

### 2.3.1 Volume

As mentioned earlier, over the past four years, the number of Locator units shipped has increased three fold and current opportunities suggest that this growth will continue. (see Figure 2) As volumes increase, ABC is increasingly able to capitalize on economies of scales in order to reduce unit costs. While ABC has utilized overseas contract manufacturers for some time, they have been able to realize further cost savings by increasing the lot sizes and volumes processed. However, as ABC places larger orders with suppliers and the supply chain grows, the risk, uncertainty and costs increase. In 2005, the average monthly demand was just over 1,000 units. It was relatively cost-effective to carry several months inventory in order to guard against uncertainty in the supply chain. In the event of poor planning, the relatively small size of the orders meant that the costs of expediting, either at manufacturing or shipping was not cost prohibitive.

By 2008, ABC on average ships more that four times as many units per month.  Stocked inventory that used to be able to buffer a full quarter's demand now lasts three weeks.  As purchasing volumes and therefore the value of  inventory and WIP increase, it becomes more important for companies to manage the costs associated with their chosen supply chain strategy.  As volume grows, the effects of poor planning, control and inventory management are amplified.  Obviously ABC wants to encourage growth and thus needs to find ways to mitigate the risk associated with larger volumes.

**Figure 2: Annual Unit Sales**



#### 2.3.1.1 Crown Telecom

In 2007, ABC signed a significant contract with a distributor in Brazil to supply locators to help combat auto theft. This opportunity was much larger than any previous deal the company had won and several hundred thousand locators were expected to be shipped over the next three years. Unfortunately, this distributor was unable secure financing and ABC was forced to write down several million dollars in inventory. For the purposes of this analysis, sales data has been adjusted so that this occurrence does not adversely skew results. While sales to Crown Telecom have not been completely eliminated, they have been adjusted to represent a more ‘typical’ large volume order.

| Period | 2007 P6 | 2007 P7 | 2007 P8 | 2007 P9 | 2007 P10 | Total |
|---|---|---|---|---|---|---|
| Crown Adjustments (units) | 15000 | 15000 | 15000 | 15000 | -20000 | 40000 |

Opportunities like the one with Crown Telecom are rare but demonstrate the importance of having a supply chain that is quickly scalable without jeopardizing overall performance. Granted, opportunities of this size are often managed outside the standard supply chain (forecasting, shipping schedules, purchasing) it is important to realize that they do contribute to the overall risk, uncertainty and volumes. As such, processes must be robust enough to accommodate these occurrences.

### 2.3.2 Variety

Like many companies looking to capture more market share and better serve the needs of their customers, ABC has continued to introduce new products and extend their product lines. This has allowed them to offer locators in a range of prices, with an assortment of feature sets and designed for a variety of applications. There is little doubt that customers have responded favourably to the increased choice offered.

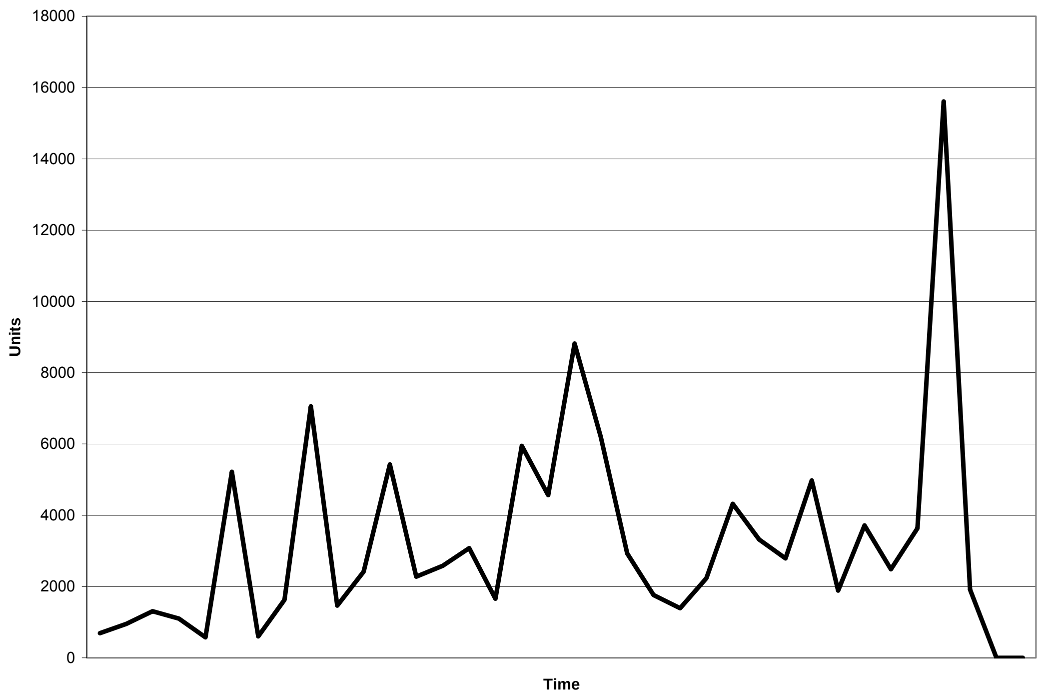
However, by offering a wider range of solutions, ABC has increased the uncertainty in their supply chain. As Amit Garg supports, “To increase their market share, many companies have extended their product lines. However, product line extension has increased the complexity of the system because of proliferation of products.” (Garg, 1997, p.29) In the last three years, the number of product varieties within a single family of locator has more than doubled. More than ever, customers are requesting new combinations and configurations of products based on their unique needs.

The most significant differentiator between varieties is the wireless modem included in the main device. Customers are able to choose other components to add to their devices such as antennas, both GPS and GPRS, weatherproof housings and cables. ABC has been using traditional make to stock supply chain strategies that were suitable for opportunities of smaller size and similar variety. As the variety of products increases, it becomes increasingly difficult to manage the range of products, especially when planning and control is mostly done manually using a ‘best guess’ methodology.

### 2.3.3 Variability

ABC experiences a great deal of variability with regards to the number of units shipped within a given period. As ABC’s business becomes more focused on government and large fleets, the affects of strong sales within a given period are amplified. We can see by figure 3 that unit sales over the past three years are anything but constant.

**Figure 3: Total Unit Sales (2006-2008)**




To add to the complexity, the increased variety of product has meant that ABC has needed to account for variability within an ever expanding range of products. Rising sales volumes and variety has in turn led to an increase in variability. Figures 4 and 5 show the variation in units shipped for each product family. As more products varieties are introduced, we observe more variability within any single product.

**Figure 4: WT6000 Unit Sales (2006-2008)**

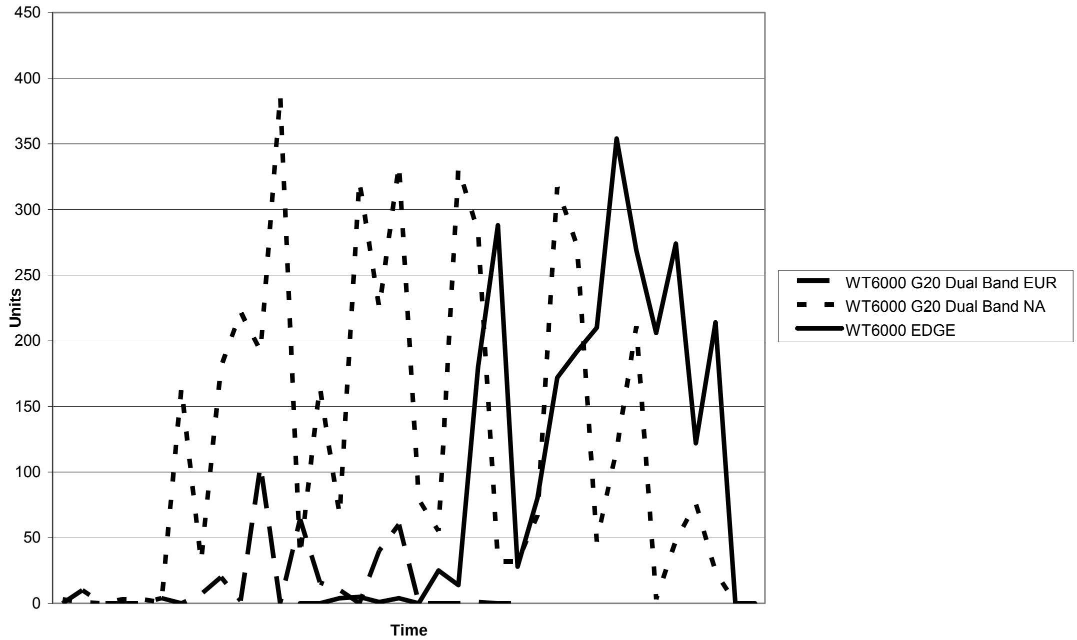
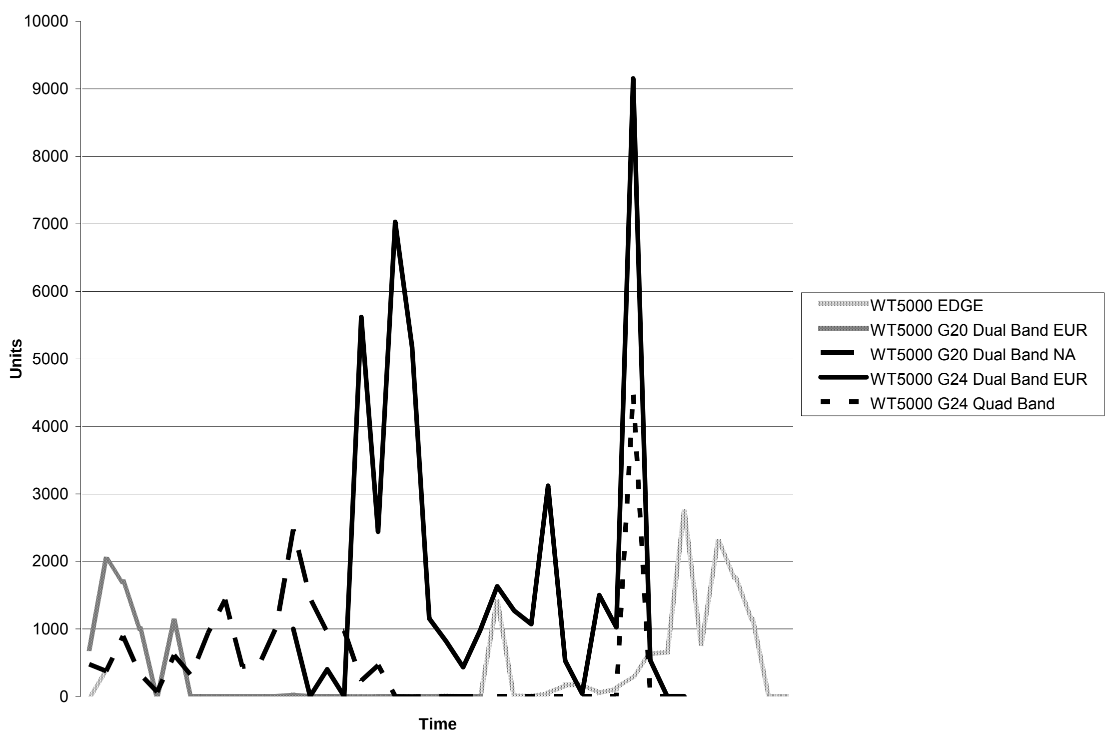



**Figure 5: WT5000 Units Sales (2006-2008)**



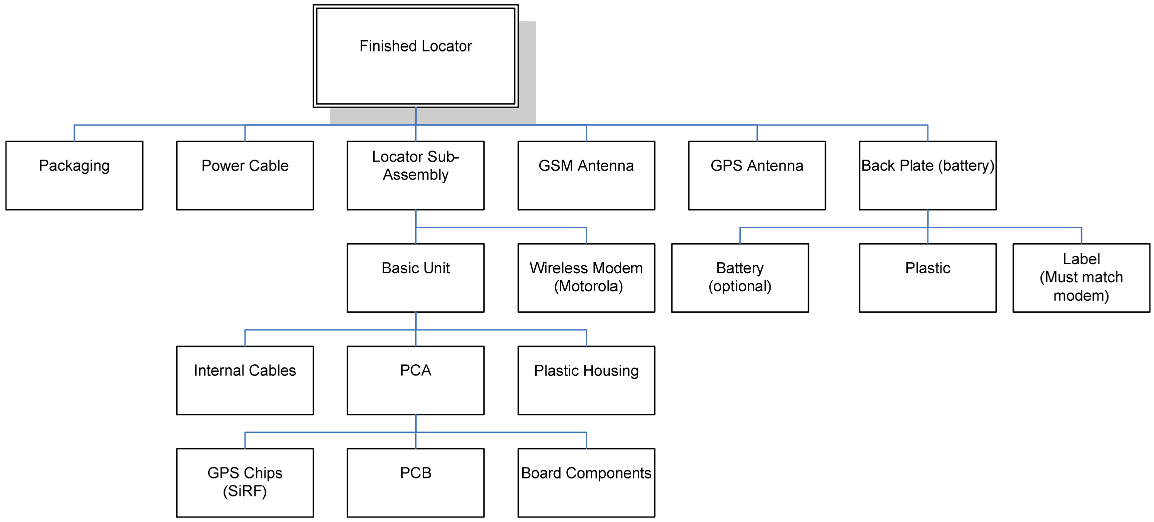
## 2.4 Inventory Management (complexity management)

ABC's recent focus on supply chain activities has brought to light issues concerning their management of inventory. Specifically, there are three main areas of improvement within inventory management: the Bill-of-material, Lead-Times and Version Control. Current BOM, manufacturing processes and chosen vendors have resulted in extremely long lead-times for products and components. This lead-time, when combined with poor visibility of on-hand inventory has meant that ABC has needed to expedite parts or components at great expense.

### 2.4.1 Bill-of-Material and SKUs

At the root of ABC's problem with Bill-of-Material (BOM) is that within their systems, Locator BOMs are inconsistent in structure and often do not reflect the physical goods being managed. This has lead to confusion within the manufacturing, operations and sales departments as to how the locator product built and what components actually make up a device. One of the most significant, differentiating and highest cost components within the locator is the wireless modem. As mentioned earlier, over the past three years ABC has been manufacturing locators with a greater variety of modems. Inaccurate BOM combined with the increased variety and volume has resulted in poor visibility to on-hand inventory or the status of WIP. ABC has found it difficult to fully leverage and utilize their Enterprise Resource Planning (ERP) software in order to gain control of their inventory. Below is an example of a 'typical' BOM for one of ABC's locators.

**Figure 6: Locator Bill-of-Material**




### 2.4.2 Lead-Times

ABC's locators suffer from long lead-times as a result of the utilization of low-cost contract manufacturers overseas. Utilizing CMs is essential to producing products at competitive costs. CMs are responsible for manufacturing and assembling the Locator subassemblies and back plates (see figure 6), the two major components to any locator. Recently, in part because of increasing volumes, ABC has chosen to ship product via ocean transport versus air. While the cost savings from utilizing CMs and ocean transport are significant, they have increased the lead-time for product. In the current manufacturing process, these are the most significant factors driving lead-times in the supply chain. In ABC's case, lead-times for critical components are as far out as 13 weeks. This in turn creates many of the problems experienced and discussed later in respect to Planning and Control.

### 2.4.3 Variety and Version Control

As customer's needs diversify, it has been necessary for ABC to increase the variety of products offered. Recently, modem varieties have been a major differentiating factor between locators and it has become obvious that tracking modem type, modem firmware version and PCB revision number is important for inventory management. Having this level of granularity was not critical when volumes and varieties were relatively small. However, as product variety increases and demand variability is amplified by the expanding product line, being able to manage and control versioning is critical. While tracking versions and variety is important throughout the product life cycle, it is especially important for effectively coordinating the end-of-life (EOL) for a product.

ABC has turned to its ERP system to help them manage the increasing variety and versioning of the product. Unfortunately, inconsistent BOM and limitations in the software has meant ABC has found it difficult adapting their BOM and SKUs to manage versioning and varieties. ABC's management is resistant to expand the number of stocked SKUs as they recognize that this introduces added complexity into the system. By exposing their sales team to a complete and granular list of products, customer would forced to make variety decisions earlier in the sales cycle. While sales representatives would assist in this task, it adds unwanted complexity. However, we will see in the 'Forecasting' section that it is critical that sales people explicitly state variety in order to gain visibility to the sales pipeline. ABC is trying to reduce complexity in the supply chain at the expense of variety and version control and thus negatively affecting inventory management.

## 2.5 Planning and Control (uncertainty management)

At the core of most supply chains is their ability to effectively plan and control the flow of raw materials into finished goods. The ability to plan and control are influenced and reliant on other aspects of the supply chain. In ABC's case, issues with inventory management have reduced their ability to effectively plan and account for uncertainty. This, in turn prevents them from further optimizing inventory levels, improving their customer service and overall reliability of the supply chain. Many of the activities in the planning and control realm of supply chain management are focused on managing uncertainty. Forecasting, purchasing/inventory levels and safety stock are all means to account for ambiguity in the system.

### 2.5.1 Forecasting

In order to gain visibility to forthcoming demand, ABC has looked to forecasting to drive its purchasing and overseas manufacturing. Due to the short product life cycle, there is limited sales history that could be used with quantitative forecasting techniques. Instead, ABC is using a qualitative approach to forecasting, using a panel of sales representatives who generate a list of current opportunities that provide a best estimate of future sales. Opportunities are weighted according to their progress in a pre-defined sales process. The long sales cycle should mean that there is good visibility to orders coming down the sales pipeline. To some extent this is true but there are several factors that have severely hindered the accuracy and effectiveness of the forecasts.

First, while there is good visibility to the opportunities in the sales funnel, the highly competitive nature of the industry means that there is lingering uncertainty as to whether an opportunity will be won. It is common for opportunity's estimated closed date (the date the opportunity is finally realized) to be pushed back repeatedly. Second, there is little visibility to the product mix of each opportunity. Again, the competition means that customers are often quoted several times before a final solution is chosen. Thirdly, the sales team is not disciplined in maintaining the CRM system that drives the forecast. Opportunities are often not updated in a timely fashion or the dates and products included are not accurate. Finally, the sales funnel is being used for two different purposes, both as a sales tool and as a forecasting tool. Sales reps use the funnel to communicate to management, progress towards their sales targets. There have been several cases where significant opportunities (500+ units) have appeared or remained in the sales forecast despite the fact that they are unlikely to close in the near future. Alone this optimism may not be significant but we must realize that individuals naturally over estimate their abilities to reach goals and that resulting inaccuracies ripple through the organization and affect other business units. (Lovallo, 2003) If these forecasts are used for purchasing, over optimistic funnels would lead to excess inventory.

For many products, including ABC's locators, the accuracy of forecasting improves as the forecasting horizon shortens. While this observation may seem obvious and has been supported by literature (Whang, 1998, p.68) there can be many factors influencing the accuracy of forecasts. Table 2 represents the forecast versus actual sales volumes for ABC's North American sales team. ABC only recently begun formalizing their sales forecasts but we can see from the limited data collected that forecasts accuracy is on average several hundreds of units off, even for the current period! What is more dramatic is that forecasting more than two periods out seems give little indication of forthcoming demand. This would suggest that effective forecasting would be limited to two periods, shorter than what is needed when working with long lead-time products.

**Table 2: North American Sales Forecast (units)**

| | Actual | Forecast Current Period | Forecast P-1 | Forecast P-2 | Forecast P-3 | Forecast P-4 | Forecast P-5 | Forecast P-6 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Jul-08 | | | 10276 | 10198 | 6763 | 6519 | 6569 | 5650 |
| Jun-08 | | 362 | 339 | 88 | 72 | 72 | 72 | 72 |
| May-08 | 594 | 404 | 351 | 1 | 1 | 0 | 0 | 0 |
| Apr-08 | 59 | 4091 | 1009 | 0 | 0 | 0 | 0 | |
| Mar-08 | 1088 | 387 | 87 | 1 | 0 | 0 | | |
| Feb-08 | 1251 | 3510 | 3097 | 0 | 0 | | | |
| Jan-08 | 1145 | 522 | 85 | 0 | | | | |
| Dec-07 | 584 | 4674 | 1567 | | | | | |
| Nov-07 | 73 | 114 | | | | | | |
| Oct-07 | 592 | | | | | | | |
| Sep-07 | 230 | | | | | | | |
| Aug-07 | 1116 | | | | | | | |

In most industries, especially retail, if forecasts lead to excess inventory, product must be discounted to dispose of it. While this has not been the case with ABC, new products have been delayed in order to clear inventory of product approaching EOL.

### 2.5.2 Purchasing and Inventory Levels

Increased volumes have allowed ABC to take advantage of economies of scale with their CMs. In order to reduce marginal cost per unit, ABC has placed larger purchase orders with vendors. While these large purchase agreements allow ABC to manufacture at lower costs, they also introduce some rigidity making the supply chain less agile. For CMs, large orders with defined production schedules reduce uncertainty and they are willing to charge less to reduce ambiguity within their own supply chain. For ABC, this means that they take on some of the risk as they are committing to purchase for orders that have yet to be realised. This strategy is ideal for situations where demand is known or there is little uncertainty in the system. However, as variety and variability of orders increases, ABC exposes themselves to increased risk.

In order to mitigate some of this risk, ABC has purchased and holds component inventory at their CMs and as WIP at their Canadian manufacturing facility. This excess inventory helps to reduce lead-times and reduces some of the uncertainty within the supply chain but introduces slack. Slack can take the form of regular inventory or as safety stock. In order to account for the high variability in demand, the level of slack needs to be enough to handle fairly large swings in demand volumes. This is especially the case with wireless modems, one of the highest cost components. As the product line expands and there is increasing variety, slack must be introduced for these produces as well. Safety stock must be held for each locator variety both as components and as finished goods.

As mentioned earlier, excess inventory makes EOL difficult and supply chain uncertainty makes transitioning between products challenging. Besides adding additional holding costs, slack increases the risk of obsolescence and exposes both the CM and ABC to the risk of theft, damage and loss of product. Holding more inventory in the supply chain increase the overall complexity of the system and as variety and volumes increase, the effort needed to control and manage these inventories increases.

### 2.5.3 Stockouts

Failures in inventory Planning and Control leads to shortages, otherwise known as stockouts. While these occurrences are rare, ABC has experience a handful of these events over the past three years. While management has been able to handle these events gracefully, often by expediting product at the expense of the company, the long-term effects of these events may be harder to measure. According to Akif Bulgak, "Estimating the back order penalty (stockout costs) that result from a lost sale is often difficult, companies set safety stock levels for products by setting a service level. Stockout costs include components such as loss of goodwill and delays to other parts of the supply chain." (Bulgak, 2006, p.5) While stockout events have not been customer facing, they have certainly tarnished the image of the operations and planning departments internally. Management recognizes the importance of eliminating these events at yet has not formally set a service level or defined a level of safety stock. In ABC's case, formal safety stock would be introduced and held at the Canadian warehouse and in case demand ever exceeded expectations. The sole purpose fo this inventory is to "counter uncertainty". (Bulgak, 2006, p.6)

# 3: SUPPLY-CHAIN STRATEGIES

Activities within a supply chain are highly integrated: outputs from one activity become the input for another. Because these activities are coupled so tightly, uncertainty and complexity can ripple throughout the supply chain, especially when there is no clear goal or common expectation within the supply chain. Purchasing may be focused on reducing costs; and, for them, tradeoffs in lead-time may seem minor. However, these decisions may have negative affects further down the supply chain. The first step in creating alignment within the supply chain is recognizing what strategy is appropriate for your organization and product.

## 3.1 Alternatives

Marshall Fisher initially introduced the idea of aligning supply chain strategies to the demand uncertainty of the product. (Fisher, 1997) Hau Lee extended this framework to take into consideration supply uncertainties, which he presents as his Uncertainty Framework. (Lee, 2002) Lee suggests that depending on on the extent of uncertainty that exists, both demand and supply side, the ideal supply chain solution can vary dramatically. In Lee's framework, products are classified as two types, Functional and Innovative, based on demand uncertainty. Supply chain processes are then characterized as two types based on supply chain uncertainty, Evolving and Stable.

Lee defines Functional Products as "ones that have long product life cycles and therefore established demand", while Innovative Products "that have short life cycles with high innovation and fashion contents – and which, as a result have highly unpredictable demand.” (Lee, 2002, p106) Similarly, Stable supply chains processes are defined as ones “where the manufacturing process and underlying technology are mature and supply base is well established.” Evolving supply chain process are ones, “where the manufacturing process and underlying technology are still under early development and are rapidly changing, and as a result the supply base may be limited in both size and experience.” (Lee, 2002, p107) Lee further characterizes products and supply chain processes in tables 3 and 4.

**Table 3: Demand Characteristics**

| Demand Characteristics | |
|---|---|
| Functional | Innovative |
| Low demand uncertainties | High demand uncertainties |
| More predictable demand | Difficult to forecast |
| Stable demand | Variable demand |
| Long product life | Short selling season |
| Low inventory cost | High inventory cost |
| Low profit margins | High profit margins |
| Low product variety | High product variety |
| Higher volumes per SKU | Low volumes per SKU |
| Low stockout costs | High stockout cost |
| Low obsolescence | High obsolescence |

Source: Lee, 2002, p.106

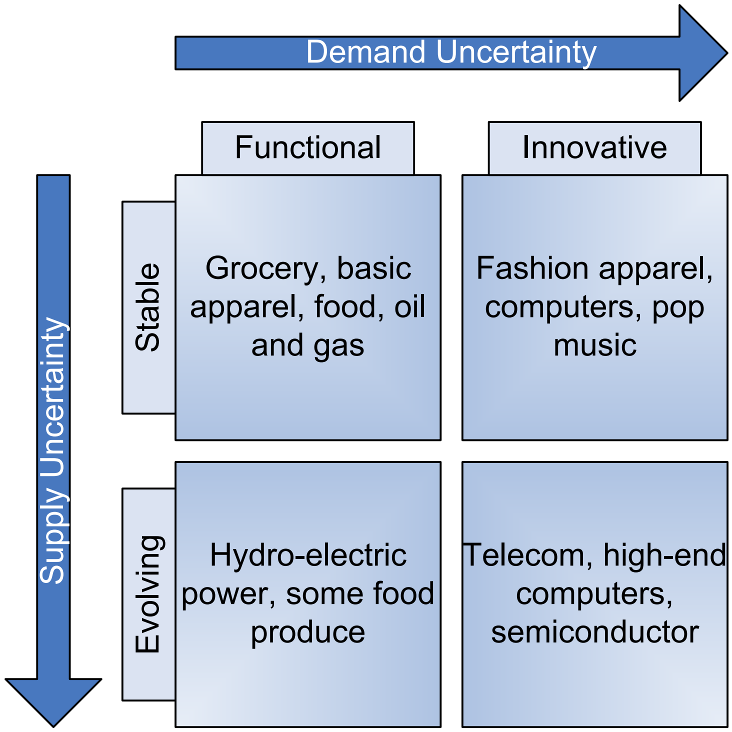
**Table 4: Supply Characteristics**

| Supply Characteristics | |
|---|---|
| Stable | Evolving |
| Less breakdowns | Vulnerable to breakdowns |
| Stable and higher yields | Variable and lower yields |
| Less quantity problems | Potential quality problems |
| More supply sources | Limited supply sources |
| Reliable suppliers | Unreliable suppliers |
| Less process changes | More process changes |
| Less capacity constraint | Capacity constrained |
| Easier to changeover | Difficult to changeover |
| Flexible | Inflexible |
| Dependable lead-time | Variable lead-time |

Source: Lee, 2002, p.107

The result is a two-by-two matrix that helps differentiate products and industries. Those industries and products whose demand and supply chain are established are positioned in the top-left corner where as highly-innovative, cutting edge industries and products are in the bottom-right. While it may seem obvious that supply chains in these industries behave differently, it is important for companies to recognize which quadrant they operate in. For firms to improve their supply chain performance, they must choose to either adapt their supply chain strategy so that it is aligned to the uncertainty of their market or if possible, find ways to reduce the overall demand or supply uncertainty. Within the matrix, Lee has identified effective supply chain strategies that are in alignment to the demand and supply characteristics.

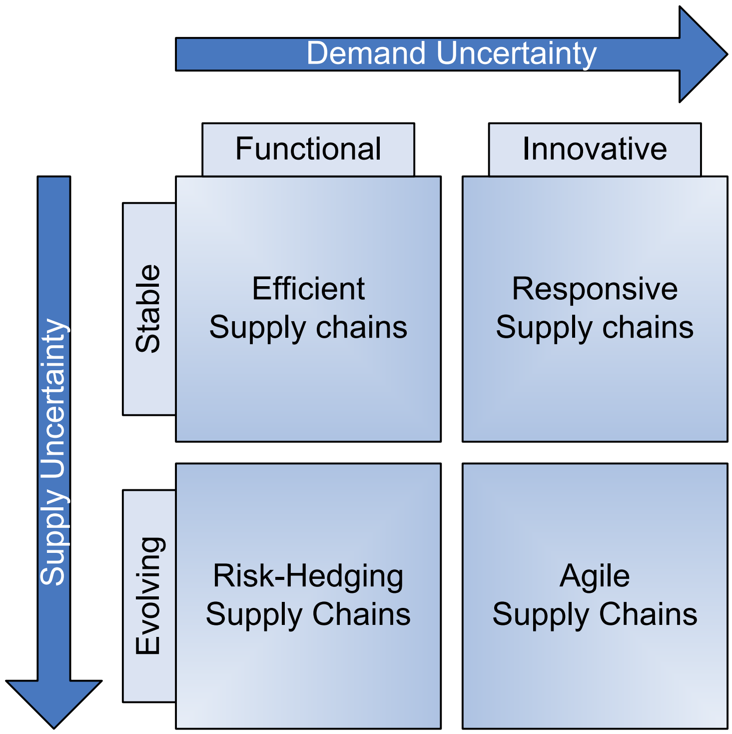
**Figure 7: Uncertainty Framework**




Source: Lee, 2002, p. 108

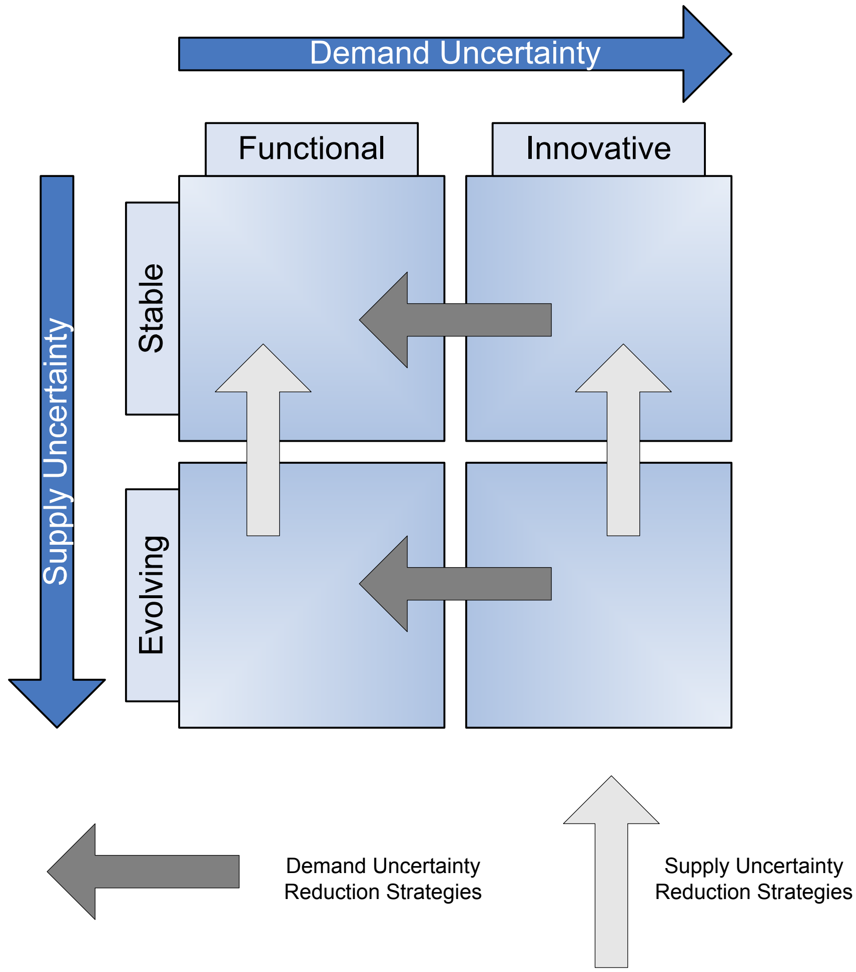
Efficient supply chains, concentrate on minimizing costs and focus on efficiency. These strategies are able to operate with little slack in the system and are often seen as the ideal model for supply chains. Because cost is so easy to quantify, most firms will try to create supply chains that operate in the top left quadrant. However, as ambiguity and complexity increases it may not be possible to reduce uncertainty enough to allow efficient strategies to be implemented effectively. As supply uncertainty increases, firms should look to risk-hedging supply chains to protect themselves from supplier uncertainty. As demand uncertainty increases, responsive supply chains allow companies to take advantage of supply side efficiencies but still have the flexibility to respond to ambiguous market conditions. Finally, agile supply chains are ideal for industries or products that operate in highly uncertain environments. There are tradeoffs between alternative strategies. We will examine four popular supply chain strategies to see how they manage demand and supply uncertainty.

**Figure 8: Matched Strategies**




Source: Lee, 2002, p. 114

**Figure 9: Uncertainty Reduction**




Source: Lee, 2002, p. 109

### 3.1.1 Make to Plan

Simply put, Make to Plan (MTP) supply chains manufacture goods based on a long-term forecast or plans. These supply chains are characteristic of industries exploiting economies of scale and that have good visibility to future customer requirements. Along with strategies such as Just-in-Time (JIT), 'Efficient' supply chains make strong use of automation, facilities layout and workflow management. Implementation of these strategies is reliant on information coordination and planning.

Common in commodity industries, these products have little variety or demand variability and are able to utilize large production volumes to their advantage. According to Lee, "When products have both low demand and supply uncertainties, the basis of competition is efficiency, " (Lee, 2002, p.115) and firms look to reduce costs at all points in the supply chain. As mentioned earlier, because the complexity of this strategy is low and the benefits, primarily reduced costs, are easily quantifiable, most companies strive to implement and achieve effective MTP supply chains.

### 3.1.2 Make to Stock

Make to Stock (MTS) supply chains are an extension of the MTP strategy mentioned above. MTS supply chains offer more flexibility in terms of production, often using forecast with a shorter horizon, but differ in that they carry inventory pools to deal with uncertainty in the system. It is in these 'risk-hedging' supply chains where inventory pools are effective. They act as a decoupling point, shielding the supply chain from supply or demand uncertainties. (Lee, 2002) These supply chains allow firms to deal with imperfect information, either from inaccurate forecasts or unreliable suppliers but trade-off efficiency by carrying excess inventory. These supply chains are able to deal with uncertainty caused by variability by creating a buffer within the system.

Risk-hedging, and specifically MTS supply chains are where many companies sit while striving to achieve an 'Efficient' solution. However, where they fail is that they incorrectly identify and address the source of uncertainty in the system. For both MTP and MTS strategies, "For companies that make to forecast, this often leads to high market mediation costs." (Shen, 2005, p.4) These costs occur when imperfect planning or systems integration leads to shortages or excess inventory. In the case of shortages, the result may be lost sales or ill-will while excess inventory may force the firm to discount product.

### 3.1.3 Assemble to Order

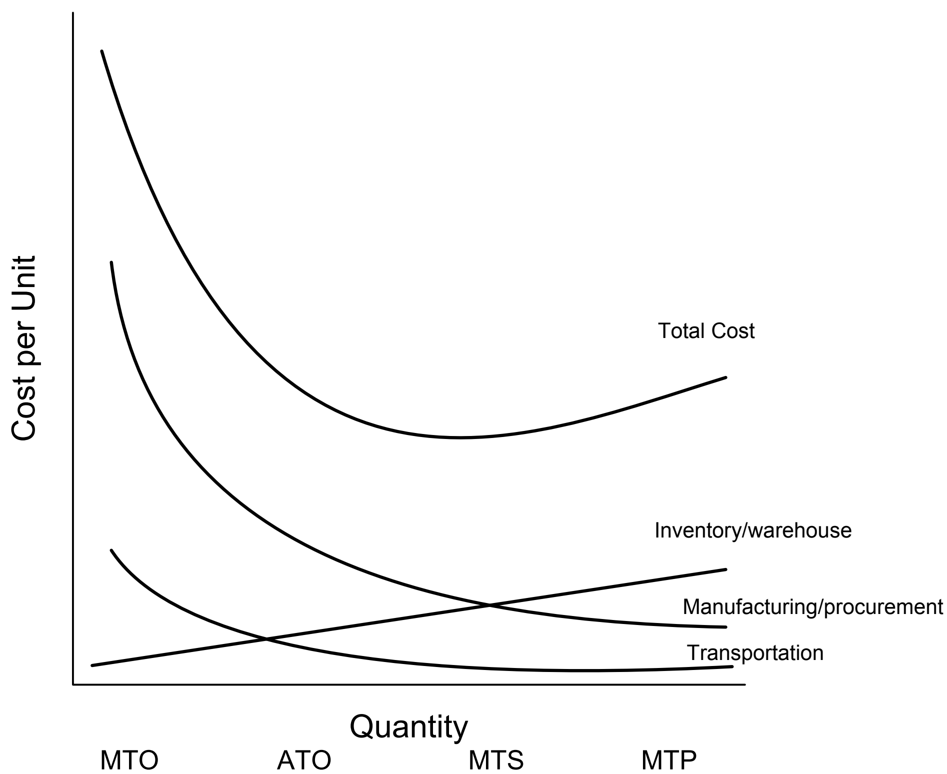
Assemble to Order (ATO) or 'Responsive' supply chains are able to gain some of the cost benefits achieved through economies of scale while remaining flexible and agile. Within ATO supply chains, base products and components are manufactured in anticipation of future customer demand. Once demand has been realized, products are assembled to the customers' requirements. While ATO strategies may have slightly higher costs, they are less affected by environments that have high variability or variety. Lee explains why firms would choose ATO strategies over the strategies focused on reducing manufacturing costs, suggesting that, "With highly unpredictable demand, excessive inventory may result. The cost of inventory for innovative products can be significant since product life cycles are short. Companies with such products should pursue strategies with a 'responsive' supply chain" (Lee, 2002, p116).

ATO strategies allow companies to customize products and respond to customer needs. ATO often allows companies to minimize total cost (see figure 10) while remaining agile. You will notice that, while manufacturing cost may be higher then those of MTS or MTP strategies, reduced inventory and WIP means the inventory costs/holding costs and transportation costs tend to be lower.

### 3.1.4 Manufacture to Order

Manufacture to Order (MTO) supply chains are designed for environments that are highly complex and uncertain. Industries or products that would benefit from MTO strategies are highly innovative, technologically advanced or manufacture to customer specifications, often referred to as ‘jobbing’. These products tend to be manufactured in extremely low volumes, have high variability in demand and since every product may be different, high variety. In return for this level of service, firms are able to charge a premium for these goods and as such, manufacturing costs are less important in MTO strategies. Instead, firms focus on responsiveness and the ability to match the customers needs in a timely fashion.

**Figure 10: Total Cost of Manufacturing**




Source: Bowersox, 2002, p.155

## 3.2 Current Strategy – Focus on Cost

ABC's current approach to supply chain strategy employs characteristics of both ATO and MTS strategies. There has always been some level of assembly and configuration for ABC's locators but physical inventory management has always focused on traditional MTS techniques. The highly-competitive environment of fleet telematics has meant that minimizing manufacturing costs have always been a pressure on ABC's supply chain. As volumes have increased, ABC has been able to realize dramatic economies of scale reducing production costs while shipping volumes has made low-cost ocean transportation practical. These cost benefits are tangible and easily quantifiable but there have been tradeoffs in lead-time and responsiveness.

Management has recognized the side-effects of their 'efficient' supply chain strategy, and within the organization are trying to stress the importance of forecasts while trying to implement more advanced inventory management techniques. Unfortunately, issues with version and variety management and visibility to customer demand remain. Meanwhile, the value of inventory assets within the supply chain continues to increase yet ABC's service level, the ability to fulfil orders within standard supply chain processes, has not improved. If ABC chooses to focus on costs move further towards an 'efficient' supply chain, they must take steps to reduce demand uncertainty for the product and minimize complexity in the system. This may be done by manufacturing a generic product, thereby eliminating variety or by taking measures to smooth demand.

## 3.3 Best Fit – Balance Cost and Agility - Assemble-to-Order

ABC should instead shift the focus of their supply chain to become more responsive and less focused on minimizing costs. For ABC, ATO strategies are ideal as they allow ABC to continue to benefit from economies of scale while offering a greater degree of flexibility, similar to MTO. ABC's locators are Innovative products and it would be difficult for ABC to minimize the degree of demand uncertainty needed to be successful implementing an efficient supply chain. ATO strategies allow companies to mitigate risk created by offering variety, primarily through component commonality and risk pooling.

ATO strategies allow supply chains to operate with imperfect information, leaving most of the value-added activity until orders are received and perfect information is available. Hewlett-Packard (HP) is well known for having found success with ATO strategies within their DeskJet printer division. Like ABC's locators, HP's printers experienced large volumes, short product life-cycles, high variability in demand and pressures to remain competitive on cost. Similarly, HP like ABC found that "forecasting the mix of options that customers want is most difficult at the beginning and end of a product's life cycle. Shorter life cycles, in particular, increase uncertainty". (Feitzinger, 1997, p.118) HP's adoption of ATO strategies not only allowed them to deal with uncertainty, it allowed them to improve overall supply chain performance.

We have seen that the nature of ABC's product and industry make it ideal for ATO supply chain strategies. ATO supply chains allow ABC to manage the uncertainty and complexity that is at the root of their inventory management and planning difficulties while allowing ABC to capitalize on efficient manufacturing processes. The following section explores an appropriate ATO supply chain strategy for ABC.

# 4: ASSEMBLE-TO-ORDER

In order for ABC to implement an ATO supply chain, they must reduce the risk and uncertainty in the system. Improving lead-times and demand forecasting are both valid techniques for reducing demand uncertainty while redesigning the product for modularity mitigates risk associated with high variety and variability. However, one of the most popular and successful means for achieving ATO supply chains is postponement.

## 4.1 Lead-times

Improving product lead-times would allow ABC to carry less inventory and be more responsive in the face of demand uncertainty. However, currently the most significant factors contributing to long-lead-times are the utilization of CMs manufacturing overseas and ocean transport. Management estimates that using an overseas CM reduces the cost for the PCA and basic unit assembly by three quarters. Likewise, ocean transport costs about one fifth of that of air. The trade-off between cost and responsiveness is clear, in order to keep costs low ABC must continue to utilize these forms of manufacturing and transportation. While it may be possible to improve lead-times elsewhere in the supply chain, these improvements would likely be negligible.

## 4.2 Forecasting

ABC has been utilizing demand forecasting with limited success for some time. Management recognizes that improving the accuracy of forecasts reduces demand uncertainty, thus allowing for effective planning and control activities. Sophisticated forecasting techniques have been developed to help determine the demand for a variety of brands, package sizes and versions. (Zinn, 1988) However, ABC, like others, has found that accurate forecasting is difficult, especially as the portfolio of products increases. (Garg, 1997) (Muzumdar et al., 2003)

If ABC were able to significantly improve the value of their forecasts, there would be a correlated reduction in safety stock. (Bulgak, 2006) Unfortunately, the nature of ABC's sales process, combined with current forecasting techniques suggests that it would be difficult to obtain accurate demand estimates. Currently, the sales department is the only business unit within ABC with direct visibility to forthcoming demand. Because individuals in this team are focused and held accountable to sales targets, it would require a major shift in behaviours for them to generate forecasts devoid of any bias towards sales quotas or influenced by optimism.

## 4.3 Product Modularity

Modularity acts differently than improving lead-times or forecasting in that its aim is not to reduce demand uncertainty. Instead modularity, defined as the "degree to which a system's components can be separated and recombined" (Schilling, 2003 p.172) allows risk to be pooled, thus reducing the impact of variety and variability while reducing overall complexity. Modularity creates a loose coupling between components and products, (Blecker, 2005, p.163) enabling a large variety of products to be produced at low cost.

ABC currently employs some level of modularity but this is limited to low-cost components such as antennas. Redesigning the basic Locator to take advantage of modularity would allow for modems and boards to be 'swapped' or recombined at will. While this solution is attractive and something ABC should seriously look at in the future, currently it would require an expensive and time-consuming redesign of the core product.

## 4.4 Postponement

Van Hoek defines postponement as "an organizational concept whereby some of the activities in the supply chain are not performed until customer orders are received. Companies can then finalize the output in accordance with customer preferences and even customise their products." (Van Hoek, 2001, p.161) The objective of postponement is similar to that of modularity in that it maintains components or products in a generic, uncommitted form until demand has been realized. Unlike modularity, postponement allows for final manufacturing and assembly to take place once the customer places an order. Postponement reduces the risk of incorrect manufacturing, product obsolescence and poor inventory management decisions while supporting expanded product variety through pooling risk.

Also known as 'delayed differentiation', (Muzumdar et al., 2003), postponement has been proven to enable companies to significantly reduce inventory, safety stock and WIP while offering improved responsiveness. According to Muzumdar, the primary drivers for companies to implement postponement are: (Muzumdar et al., 2003)

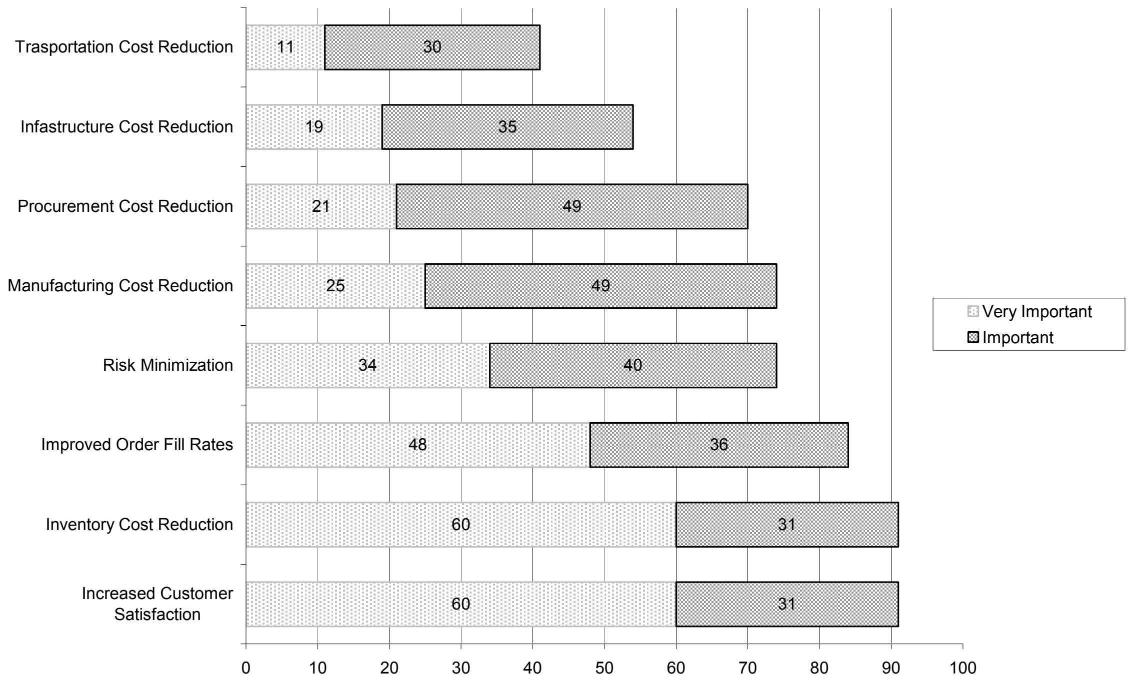
- 73% noted increased difficulty to forecast demand

- 60% noted customers demanding higher levels of customization As companies compete globally, customization of goods is often required on a country-by-country basis.
- Inventory costs, including inventory obsolescence, are rising as companies attempt to meet customer demand
- A new wave of managers is addressing the supply chain with strategic solutions

(See Appendix A)

Many of these drivers are similar to ones experienced by ABC within their supply chain. This suggests they are a prime candidate for postponement. What is more impressive are the results and benefits realized by companies that implement this supply chain strategy. Over 90% of companies achieved a reduction in inventory costs and improved customer satisfaction, followed closely by improved order fill rates and reduced risk.

**Figure 11: Benefits of Postponement**




Source: Muzumdar et al., 2003

Within ABC's current manufacturing process there is a tremendous opportunity to take advantage of postponement. Sourcing modems adds several weeks to the overall lead-time, account for close to a third of the overall unit costs and are one of the most significant differentiating features within each product family. Most importantly, modem variety acts to differentiate the product early in the supply chain. By postponing the final manufacturing (inserting modems), ABC would be able to reduce uncertainty and risk and thereby reduce inventory and improve responsiveness. This would be possible without redesigning the product, significantly changing people's behaviours or sacrificing cost savings achieved through low-cost shipping and manufacturing. The following section will demonstrate how postponement could be applied at ABC Wireless, its pros and cons and how it would benefit the company both strategically and financially.

Potential cost savings derived from implementing postponement will allow ABC's management to determine a net return-on-investment (ROI) if they choose to pursue this supply chain strategy.

# 5:  RECOMMENDATION - POSTPONEMENT

As ABC's supply chain has developed, it has evolved into a push production system, whereby manufacturing drives and generates inventory that will in turn fulfil demand.  While there is some level of assembly and customization of goods in the current process, the majority of value added manufacturing occurs far upstream in the supply chain.  In 'push' supply chains, product proliferation introduces complexity into the system and in turn leads to "an exponential increase of inventory" (Blecker, 2005) as companies try to account for demand uncertainty for each product.  According to Zinn, firms such as ABC that sell products with several versions (variety),  high unit value, sales fluctuations (variability) and a high proportion of ubiquitous materials should seriously consider the value of postponement. (Zinn, 1988, p.135)

Postponement utilizes "points of product differentiation" or "decoupling points" to separate a 'push' supply chain activities, designed for efficiency, from 'pull' supply chain activities that are driven by customer demand.  In order to move these decoupling points further downstream in the supply chain, many firms re-sequence production or distribution activities. Much has been written regarding the benefits of postponement, primarily its ability to "improve the agility, flexibility and risk hedging ability of supply chains", (Shen, 2005, p.3) and its power to lessen forecasting horizons, thereby resolving uncertainty associated with product demand (Bulgak, 2006).

For ABC, if complexity can be kept to a minimum, the lack of supply uncertainty presents an opportunity to create an 'efficient', 'push' component to their supply chain.

Establishing a process whereby the decoupling point is deferred, will allow ABC to combine the cost effective activities of the ‘push’ system with ones designed to increase responsiveness and provide variety.  The critical success factors and potential benefits are presented, allowing for postponement to be compared to ABC’s existing supply chain strategy.  By juxtaposing the two, it is possible to determine the affects of postponement on overall supply chain performance.

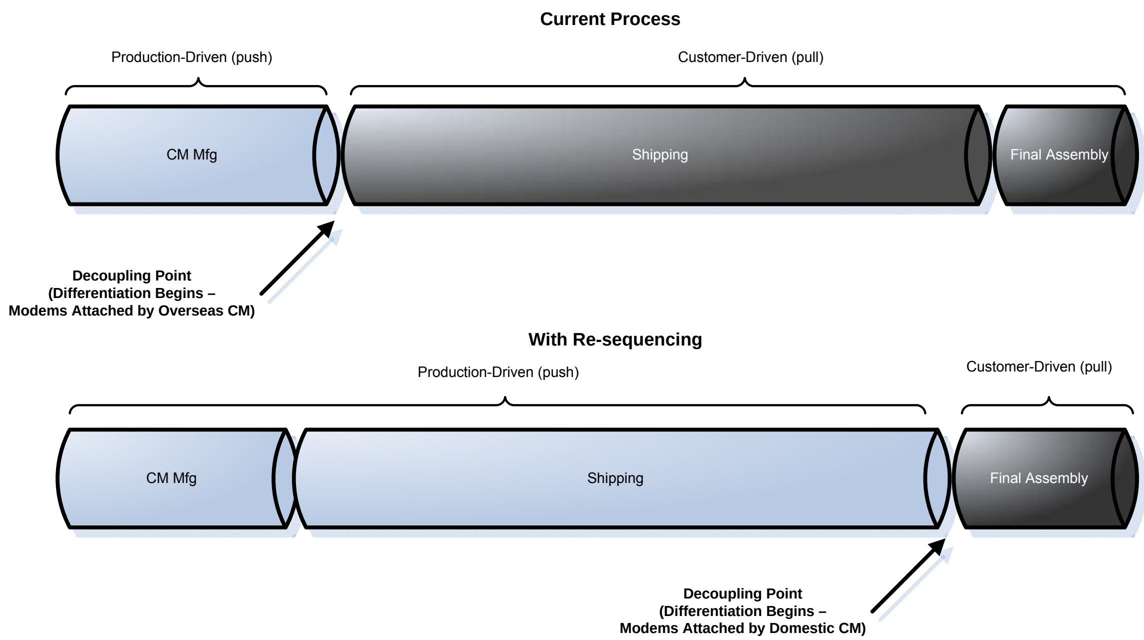
## 5.1 Delayed Differentiation

According to Lampel and Mintzberg, delayed differentiation is focused on separating the production-driven (push system) activities from the customer-driven (pull systems) activities in the supply chain.  (Lampel et al., 1997)  For ABC, differentiation begins when modems are attached to the PCA board during manufacturing.  Forecasted customer demand determines the variety of product to be manufactured and acts to pull inventory from the CM.  Up until this point, inventory remains in generic form uncommitted to any variety.  Once the variety has been determined, flexibility is lost and complexity is introduced (Garg, 1997).

### 5.1.1 Process re-sequencing

In order to postpone product differentiation and move the decoupling point later in the supply chain, it is recommended that ABC re-sequence some manufacturing activities, in particular, affixing the modems to the PCA.  While there is little doubt that overseas CMs will be able to offer this service at much lower costs than domestic CMs, it will be shown that delaying this activity will have dramatic benefits.  According to Zinn, “The postponement trade-off is an increase in per unit manufacturing costs due to reduced economies of scale", however, with postponement, "Cost reductions result from lower transportation expenditure and reduced inventory carrying costs." (Zinn, 1988, p.125) The cost for overseas CMs to attach a modem to PCA and test is approximately $1.50 per unit. If we assume that the costs savings of overseas to domestic CMs is proportional to that of the manufacturing the PCA, choosing to use a domestic CM would increase the total cost of goods by a mere $4.50.

**Figure 12: Process Re-sequencing**

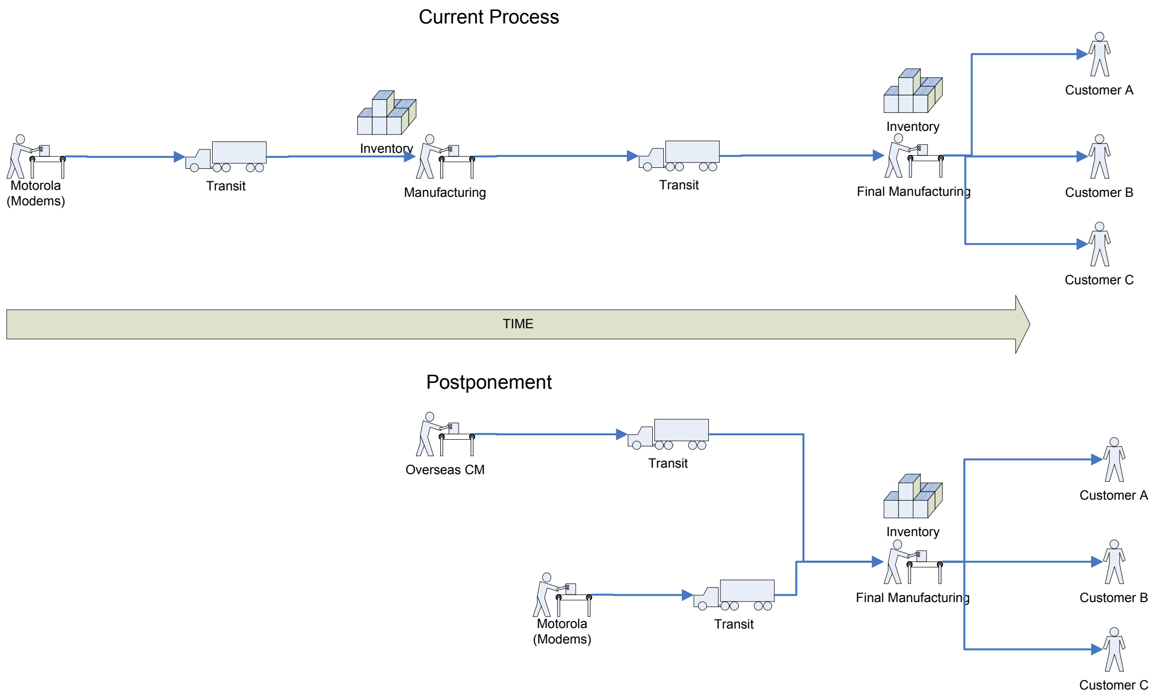



## 5.2 Reduced Lead-time

ATO strategies are designed to increase the responsiveness of the supply chain in uncertain environments. Postponement and process re-sequencing has the effect of breaking some of the dependencies between products and/or processes. For ABC, processes within their current supply chain are serial whereas postponement allows for activities to take place in parallel. For example, in the current process, modems must be ordered and received by the overseas CM before being shipped to ABC's main warehouse. Modems are in transit twice. In postponement, the re-sequencing of final manufacturing means that the PCA is shipped from the overseas CM at the same time that modems are enroute from Motorola.

Performing processes in parallel allows lead-times to be reduced dramatically, thus increasing the responsiveness of the supply chain. For ABC, postponement breaks the dependency between PCAs and modems and allows these long lead-time components to be in transit simultaneously. Lead-times for critical, costly components can be shortened by as much as 6 weeks, reducing the cash-to-cash conversion time and improving cash flow management. This reduction in lead-times is a major factor in reducing uncertainty in the system and providing flexibility within the supply chain.

**Figure 13: Reduced Lead-time**




## 5.3 Risk Pooling

By delaying differentiation and producing generic components, demand across several products can be aggregated. The cumulative demand effectively 'pools' risk and uncertainty, minimizing the effects of variability in the system. In theory, high demand from one customer or for one product will likely be offset by low demand for another. (Bulgak, 2006) Furthermore, postponement allows for component sharing between product lines so that safety stocks can be reduced. In ABC's case, if postponement is implemented, demand is pooled within each family of locators. Perhaps more importantly, critical components such as modems become communal, serving demand from multiple product lines and product families. To help quantify the benefits of postponement, a basic analytical model can be used to show how process re-sequencing and risk pooling affect supply chain performance. The model used in this analysis (see

Appendix B) determines inventory in-transit and inventory held as safety stock based on mean demand, standard deviation and a specified service level or ‘fill rate’. The results (see appendix C-G) suggest that ABC would be able to eliminate approximately 15,000 modems from inventory in-transit and safety stock due to risk pooling and component sharing between product families.

### 5.3.1 Forecasting Horizon

One result of risk pooling is that complexity and uncertainty is reduced in forecasting. By aggregating demand for end products, postponement improves the accuracy of forecasts thus reducing the risk of market mediation costs resulting from inaccurate estimates (Shen, 2005). Furthermore, the reduction in lead-times in turn shortens the forecasting horizon further contributing to improved accuracy. While forecasts are still dealing with imperfect information, the quality of this information is much improved.

As mentioned previously, forecasting has been an area of difficulty for ABC. In part, this is because the forecasting horizon was further than their visibility of sales. ABC begins to gain a firm grasp of sales approximately two months or 8 weeks prior to closing and winning an opportunity. Their forecasting horizon is barely half that of the current lead-time for modems. By re-sequencing process and by pooling demand, lead-times for PCAs and modems are within the forecasting horizon, thus mitigating the risk associated with imperfect information.

### 5.3.2 Certification and Localization

ABC's customers are geographically distributed and operate in over 40 countries on six continents. In specific markets, in order to sell hardware, ABC's locator devices must be certified by government or third party organizations. These organizations issue a unique certification number for each variety of locator subassembly (PCA and modem). These organizations stipulate that devices must be labelled exclusively with the appropriate certification number.

Currently, overseas CMs affix labels to locator back plates, a component that is physically identical between locator varieties. Not only does this introduce further variety into the supply chain, it adds the complexity by creating a dependency between to subassemblies and back plates. Back plates are tied to both a product variety but also with the geographic region that issued the certification. While it is a simple process to re-label back plates, thus transforming the component, postponement defers the process of labelling until perfect variety information is received. By delaying differentiation, ABC is able to share the back plate component between locator varieties and is no longer required to hold separate inventories that are identical in all respects with the exception of labels.

## 5.4 Reduced Inventory Costs

Delayed differentiation, risk pooling and component commonality have the effect of shifting inventory costs upstream in the form of less expensive, generic products. (Muzumdar et al., 2003) No longer is the system complicated by uncertainty resulting from high variety and variability. Instead, risk is mitigated allowing for safety stocks to be reduced without jeopardizing service levels or ABC's ability to fulfil demand. When compared to their current supply chain strategy, postponement could offer the same service level while eliminating over two million dollars worth of inventory from the supply chain. As ABC's business expands and sales volumes increase, these savings grow.

**Table 5: 2007 Value of Inventory Reduction (see Appendix G)**

| 2007 | Current Process | Postponement | Reduction | Value of Inventory |
|---|---|---|---|---|
| Total # of WT5000 Boards | 24349 | 12828 | 11521 | $1,221,222.67 |
| Total # of WT6000 Boards | 1543 | 820 | 723 | $133,719.24 |
| Total # of Modems | 25891 | 10730 | 15161 | $682,244.63 |
| | | | | $2,946,846.05 |

**Table 6: 2008 Value of Inventory Reduction (see Appendix G)**

| 2008 (10mths) | Current Process | Postponement | Reduction | Value of Inventory |
|---|---|---|---|---|
| Total # of WT5000 Boards | 33175 | 19073 | 14101 | $1,494,748.59 |
| Total # of WT6000 Boards | 1651 | 983 | 668 | $123,619.77 |
| Total # of Modems | 34826 | 20468 | 14358 | $1,507,611.54 |
| | | | | $3,125,979.90 |

ABC, like many companies, have focused on reducing the unit cost through cost-effective manufacturing that result in inventory. However, when carrying inventory, there are additional factors that must be taken into account to calculate the real cost inventory. For companies such as ABC, true inventory or holding costs can included warehousing, insurance, obsolescence or costs incurred as a result of complexity. While these figures are estimates, holding costs for technology companies typically range from twenty to thirty percent of the cost of goods. For our model, the following costs have been included as inventory holding costs:

**Table 7: Holding Costs**

| Category | % of Inventory Cost |
|---|---|
| Cost of Capital | 5% |
| Warehouse Space | 5% |
| Obsolescence | 2% |
| Damage | 1% |
| Inefficiency and Mistakes | 2.5% |
| Expedited Shipments | 1% |
| Handling Inventory | 0.5% |
| Lost business or ill-will due to delays | 1% |
| Management Time Wasted | 5% |
| TOTAL | 23% |

Postponement in ABC's supply chain offers a tremendous opportunity to reduce the cost of inventory, both as safety stock and as inventory in-transit. According to the model, in 2007, providing a service level of 98%, postponement would have been able to reduce the total cost of inventory by over $640,000 when compared to ABC's existing supply chain strategy (see Appendix C and D). In the first ten months of fiscal 2008, the savings would have been close to $675,000, a savings of over 40% (see Appendix E and F).

**Table 8: 2007 Postponement vs. Current (see Appendix G)**

| **2007** | | | |
|---|---|---|---|
| | **Current Process** | **Postponement** | **Savings** |
| Total Cost of Safety Stock | $724,241.14 | $361,302.09 | $362,939.0 |
| Total Cost of Inv in Transit | $534,924.54 | $245,464.33 | $279,460.2 |
| **Total Cost of Inventory** | **$1,249,165.68** | **$606,766.42** | **$642,399.2** |

**Table 9: 20008 Postponement vs. Current (see Appendix G)**

| **2008 (10mths)** | **Current Process** | **Postponement** | **Savings** |
|---|---|---|---|
| Total Cost of Safety Stock | $1,022,105.33 | $639,518.57 | $382,78 |
| Total Cost of Inv in Transit | $650,350.55 | $361,642.82 | $288,70 |
| **Total Cost of Inventory** | **$1,672,455.88** | **$1,001,161.39** | **$671,29** |

## 5.5 Obsolescence, Versioning and End-of-Life

It has been shown that postponement addresses demand uncertainty within the supply chain but it also serves to mitigates risk in other forms as well. Like other high-tech companies, ABC's product life cycles are short, driven by ever evolving technologies. Product obsolescence is common and it is critical that companies have the ability to stay at the forefront of technology in order to remain competitive. Postponement creates buckets of component inventory that can be drawn down from a variety of products. This improves a company's ability to consume inventory approaching obsolescence, thus allowing for new technologies to be introduced. This process, often referred to as End-of-Life (EOL), is important for seamlessly introducing new and improved products to the market. Technology companies like Dell, HP and IBM have all used ATO and postponement strategies to gain responsiveness in their supply chains, thus allowing them to entice customers with new and more profitable products (Shen, 2005).

For ABC, postponement also minimizes the complexity resulting from versioning. Like product EOL, ABC must transition between modem and PCA versions smoothly. Failure to do so results in customers receiving inferior product or in extreme cases inventory write-offs.

# 6: FURTHER RECOMMENDATIONS

As ABC's business matures, ABC's management must decide upon a supply chain strategy that is in alignment with their operational and strategic goals. It has been shown that ATO strategies, particularly postponement, is a good fit with ABC's business as it allows them to handle the uncertainty and complexity, resulting high variability, expanding variety and increasing volumes. If ABC chooses to implement postponement, there are several areas that offer opportunities for further improvement to overall supply chain performance.

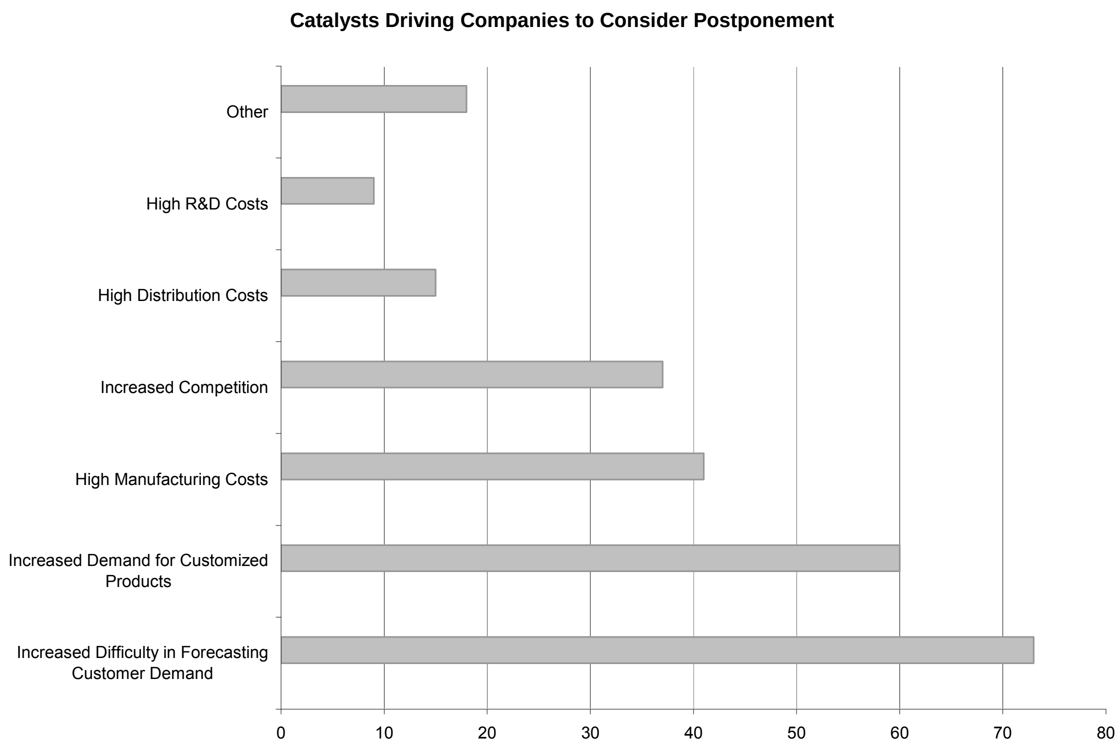
Currently, ABC aims to fulfil and ship orders two weeks after realizing demand. If final manufacturing is postponed, ABC must improve final assembly and configuration times if they hope to implement a true ATO strategy. While this may not be critical immediately, one of ABC's long-term strategic goals is to offer customers and distributors the ability to order product online. Implementing an eCommerce solution will eliminate interaction between customers and ABC's sales team, thus eliminating visibility to demand. Supply chain processes must be responsive enough to fulfil demand from a variety of sales channels in a timely fashion. Alternatively, ABC should determine their customers' limits for acceptable order turnaround time. It may be that customers are willing to wait three weeks for product, in which case, final manufacturing and assembly could happen within this time frame without achieving any improvements in order processing.

Redesigning ABC's locator products to take advantage of modularity could facilitate improvements in order processing and reduce the time needed for final manufacturing.  Modularity would allow ABC to benefit both from economies of scale and economies of scope. (Blecker, 2005)  For example, designing locators so that modems could 'snap-in' would improve manufacturing times and allow for components to be swapped easily in the field.  This would be beneficial for servicing, diagnostics and perhaps improve the efficiency of the reverse supply chain.

Finally, reducing complexity and uncertainty is critical to effective supply chains. Continued reductions in lead-times or improved accuracy in forecasting would allow for safety stock and in-transit inventory to be reduced further.  Lead-times can be reduced through improved information sharing and closer relationships with suppliers.  If ABC continues to rely on sales for its demand forecasting, it is recommended that sales forecasts and demand forecasts be driven by different stages within the sales process.  By differentiating the two and communicating the functions, sales has the ability to show progress toward their targets (usually over optimistic) while allowing for more conservative forecasts to drive supply chain activities.

# APPENDICES

## Appendix A




Source: Muzumdar et al., 2003

## Appendix B

Basic Model (Adapted from Dr. Sudheer Gupta's Lecture Notes)

In supply chain literature, many mathematical models have been presented to evaluate the benefits of postponement. These models attempt to accurately portray specific manufacturing, demand or market conditions but ultimately their conclusions on the benefits of postponement are the same.(Warburton, 2005) (Fu et al., 2006) (Hsu et al., 2006) For the purpose of this analysis, a generic model is utilized. While this model is relatively simple, it is sufficient to provide qualitative data needed to determine the benefits of postponement.

This model begins by assuming that demand per period is an independent, random variable with normal distribution. For each component, lead-time, mean demand per unit of time and standard deviation are calculated. Since sales data is collected monthly and lead-times are measured in weeks, mean demand and standard deviation per week (unit of time) are calculated. To accurately model postponement and account for the extra costs and time associated with utilizing a domestic CM, the cost of modems has been increased $5 and one week has been added to lead-times. In order to determine appropriate levels of safety stock, a cycle service level is used to indicate the percentage of demand that can be satisfied from product in inventory. For the purpose of this analysis, the service level is set at 98%, which gives us a z-value of 2.05. (see Figure 15)

| | |
|---|---|
| L | = replenishment lead-time |
| Demand Rate: $N(\mu_d, \sigma_d)$ | = Demand per unit of time (week) is normally distributed with mean $\mu_d$ and standard deviation $\sigma_d$ |
| Cycle Service Level | = Probability of no stock out<br>= P(demand during lead-time ≤ ROP)<br>= z-value ($z$) |
| Lead-time Demand ($D_l$): $N(\mu_l, \sigma_l)$ | = Demand during lead-time is normally distributed with mean $\mu_l$ and standard deviation $\sigma_l$ |
| Safety Stock (ss) | $= \mu_l + z * \sigma_l$<br>$= \mu_d * L + z * \sigma_d\sqrt{(L)}$ |
| In-Transit (it) | $= \mu_l * L$ |
| Reorder Point (ROP) | = Mean demand during lead-time + |

**Figure 14: Demand and Variability**

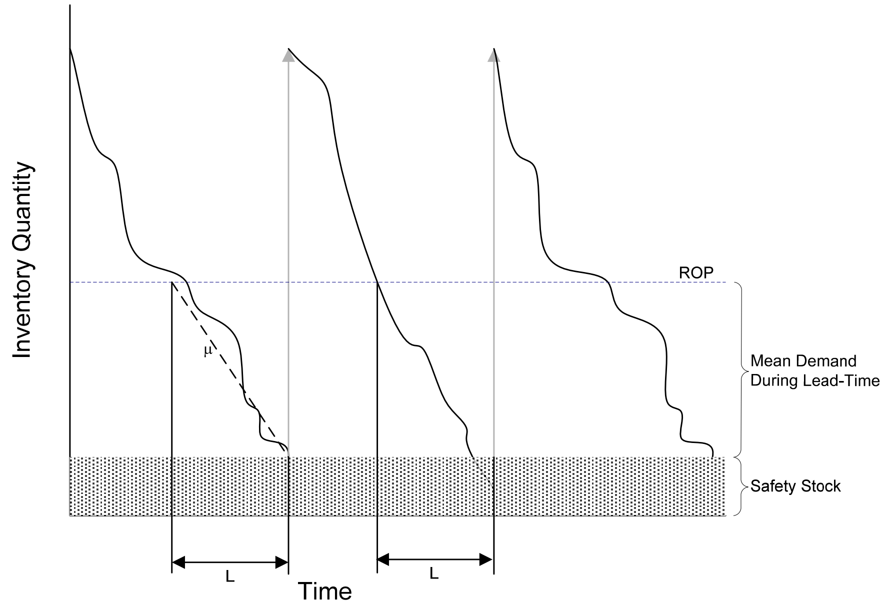
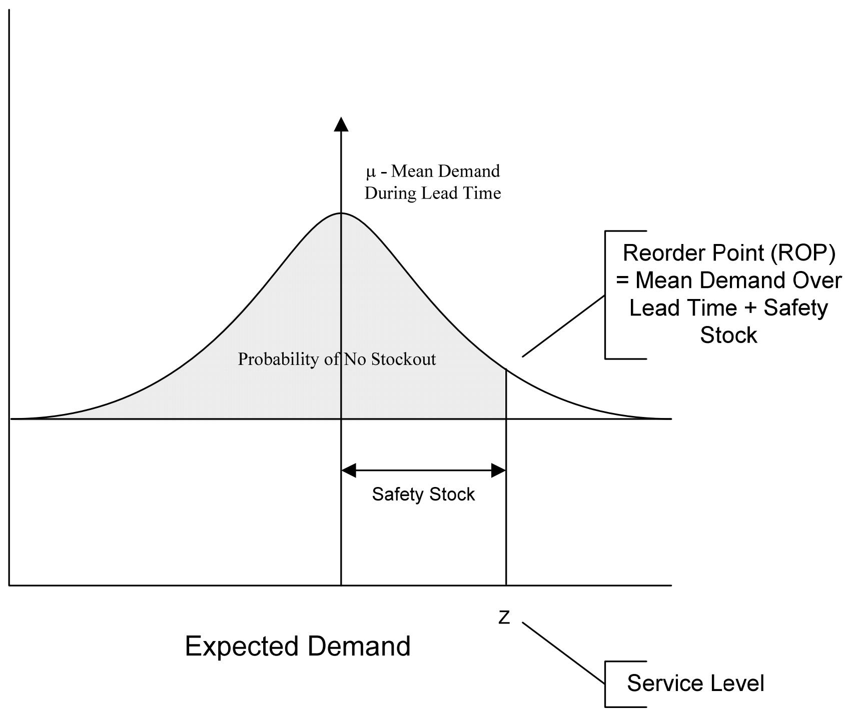



**Figure 15: Reorder Point and Service Level**




A holding cost of 23% is used to calculate the cost of inventory, both in-transit and held as safety stock.

# Appendix C

2007 - Current Process

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Carrying Cost %** | | 0.23 | | | | | | | |
| **Cycle Service Level %** | | 98 | **Z-value:** | 2.05 | | | | | |

| Locator Varieties | **Monthly Mean** | **Monthly Std .Dev** | **Weekly Mean** | **Weekly Std. Dev** | **Mean Demand During Leadtime** | **Std Dev. Of Demand During Leadtime** | **Safety Stock** | **In-Transit Inventory** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $(\mu_d)$ | $(\sigma_d)$ | $\mu_l)$ | $(\sigma_l)$ | (ss) | (It) | |
| **WT5000 SUPPLY CHAIN** | | | | | | | | | |
| Lead-time (weeks): | | 13 | | | | | | | |
| Unit Cost (board and modem est) | | 205 | | | | | | | |
| WT5000 EDGE | 149.83 | 399.04 | 34.60 | 191.77 | 449.85 | 691.42 | 1420.01 | 449.85 | |
| WT5000 G20 Dual Band EUR | 545.83 | 749.52 | 126.06 | 360.20 | 1638.76 | 1298.71 | 2667.22 | 1638.76 | |
| WT5000 G20 Dual Band NA | 613.33 | 384.34 | 141.65 | 184.70 | 1841.42 | 665.95 | 1367.69 | 1841.42 | |
| WT5000 G24 Dual Band EUR | 2086.25 | 2444.86 | 481.81 | 1174.93 | 6263.57 | 4236.26 | 8700.20 | 6263.57 | |
| | | | | | | TOTAL INVENTORY: | 14155.12 | 10193.59 | 24348.72 |
| | | | | | | TOTAL INV $ | 667414.12 | 480627.83 | |
| | | | | | | TOTAL INVENTORY COST | 1148041.94 | | |

**WT6000 SUPPLY CHAIN**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lead-time (weeks): | | 13 | | | | | | | |
| Unit Cost (board and modem est) | | 285 | | | | | | | |
| WT6000 EDGE | 45.75 | 91.40 | 10.57 | 43.92 | 137.36 | 158.37 | 325.25 | 137.36 | |
| WT6000 G20 Dual Band EUR | 15.92 | 24.52 | 3.68 | 11.78 | 47.79 | 42.48 | 87.25 | 47.79 | |
| WT6000 G20 Dual Band NA | 163.42 | 127.70 | 37.74 | 61.37 | 490.63 | 221.27 | 454.43 | 490.63 | |
| | | | | | | TOTAL INVENTORY: | 866.93 | 675.77 | 1542.70 |
| | | | | | | TOTAL INV $ | 56827 | 44296.71 | |
| | | | | | | TOTAL INVENTORY COST | 101123.74 | | |
| | | | | | | Total Safety Stock Cost | 724241.14 | | |
| | | | | | | Total In-Transit Cost | 524924.54 | | |
| | | | | | | **TOTAL INVENTORY COST** | 1249165.68 | | |

# Appendix D

2007 - Postponement

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.23 | | | | | | | |
| **Cycle Service Level %** | | 98 | **Z-value:** | 2.05 | | | | | |
| Locator Varieties | **Monthly Mean** | **Monthly Std .Dev** | **Weekly Mean** ($\mu_d$) | **Weekly Std. Dev** ($\sigma_d$) | **Mean Demand During Leadtime** $\mu_l$) | **Std Dev. Of Demand During Leadtime** ($\sigma_l$) | **Safety Stock** (ss) | **In-Transit Inventory** (lt) | |
| **WT5000 BOARD SUPPLY CHAIN** | | | | | | | | | |
| Lead-time (weeks): | | 8 | | | | | | | |
| Unit Cost | | 105 | | | | | | | |
| WT5000 BOARD | 3395.25 | 2348.06 | 784.12 | 1128.40 | 6272.98 | 3191.61 | 6554.77 | 6272.98 | |
| | | | | | | TOTAL INVENTORY: | 6554.77 | 6272.98 | 12827. |
| | | | | | | TOTAL INV $ | 159805.24 | 152935.23 | |
| | | | | | | TOTAL INVENTORY COST | 312740.47 | | |
| **WT6000 BOARD SUPPLY CHAIN** | | | | | | | | | |
| Lead-time (weeks): | | 8 | | | | | | | |
| Unit Cost | | 185 | | | | | | | |
| WT6000 BOARD | 225.08 | 144.73 | 51.98 | 69.55 | 415.86 | 196.73 | 404.03 | 415.86 | |
| | | | | | | TOTAL INVENTORY: | 404.03 | 415.86 | 819. |
| | | | | | | TOTAL INV $ | 17191.53 | 17694.77 | |
| | | | | | | TOTAL INVENTORY COST | 34886.30 | | |

**MODEM SUPPLY CHAIN**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lead-time (weeks): | | 6 | | | | | | | |
| Unit Cost (est) | | 105 | | | | | | | |
| EDGE | 195.58 | 404.61 | 45.17 | 194.44 | 271.02 | 476.28 | 978.16 | 271.02 | |
| G20 Dual Band EUR | 561.75 | 756.83 | 129.73 | 363.71 | 778.41 | 890.90 | 1829.69 | 778.41 | |
| G20 Dual Band NA | 776.75 | 400.90 | 179.39 | 192.66 | 1076.33 | 471.91 | 969.19 | 1076.33 | |
| G24 Dual Band EUR | 702.17 | 1594.43 | 162.16 | 766.23 | 972.98 | 1876.88 | 3854.65 | 972.98 | |
| | | | | | | TOTAL INVENTORY UNITS: | 7631.69 | 3098.73 | 10730. |
| | | | | | | TOTAL INV $ | 184305.32 | 74834.32 | |
| | | | | | | TOTAL INVENTORY COST | 259139.64 | | |

| | |
|---|---|
| Total Safety Stock Cost | 361302.09 |
| Total In-Transit Cost | 245464.33 |
| **TOTAL INVENTORY COST** | 606766.42 |

# Appendix E

2008 – Current Process

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Carrying Cost %** | | 0.23 | | | | | | | |
| **Cycle Service Level %** | | 98 | **Z-value:** | 2.05 | | | | | |
| Locator Varieties | **Monthly Mean** | **Monthly Std .Dev** | **Weekly Mean** | **Weekly Std. Dev** | **Mean Demand During Leadtime** | **Std Dev. Of Demand During Leadtime** | **Safety Stock** | **In-Transit Inventory** | |
| | | | $(\mu_d)$ | $(\sigma_d)$ | $\mu_l)$ | $(\sigma_l)$ | (ss) | (It) | |
| **WT5000 SUPPLY CHAIN** | | | | | | | | | |
| Lead-time (weeks): | | 13 | | | | | | | |
| Unit Cost (board and modem est) | | 205 | | | | | | | |
| WT5000 EDGE | 1046.70 | 927.43 | 241.73 | 445.70 | 3142.52 | 1606.98 | 3300.33 | 3142.52 | |
| WT5000 G20 Dual Band EUR | 1.50 | 6.24 | 0.35 | 3.00 | 4.50 | 10.81 | 22.21 | 4.50 | |
| WT5000 G20 Dual Band NA | 653.60 | 821.21 | 150.95 | 394.65 | 1962.31 | 1422.93 | 2922.35 | 1962.31 | |
| WT5000 G24 Dual Band EUR | 1987.10 | 2652.83 | 458.91 | 1274.87 | 5965.89 | 4596.60 | 9440.27 | 5965.89 | |
| WT5000 G24 Quad Band | 450.00 | 1423.02 | 103.93 | 683.86 | 1351.04 | 2465.70 | 5063.93 | 1351.04 | |
| | | | | | | TOTAL INVENTORY UNITS: | 20749.08 | 12426.26 | 3317 |
| | | | | | | TOTAL INV $ | 978319.15 | 585898.10 | |
| | | | | | | TOTAL INVENTORY COST | 1564217.25 | | |

**WT6000 SUPPLY CHAIN**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lead-time (weeks): | | 13 | | | | | | | |
| Unit Cost (board and modem est) | | 285 | | | | | | | |
| WT6000 EDGE | 209.30 | 78.00 | 48.34 | 37.48 | 628.38 | 135.15 | 277.56 | 628.38 | |
| WT6000 G20 Dual Band NA | 118.20 | 109.71 | 27.30 | 52.72 | 354.87 | 190.10 | 390.42 | 354.87 | |
| | | | | | | TOTAL INVENTORY: | 667.98 | 983.26 | 16 |
| | | | | | | TOTAL INV $ | 43786.17 | 64452.45 | |
| | | | | | | TOTAL INVENTORY COST | 108238.63 | | |

Total Safety Stock Cost 1022105.33

Total In-Transit Cost 650350.55

**TOTAL INVENTORY COST** 1672455.88

## Appendix F

2008 – Postponement

| | | | | |
|---|---|---|---|---|
| | | 0.23 | | |
| **Cycle Service Level %** | | 98 | **Z-value:** | 2.05 |

| Locator Varieties | **Monthly Mean** | **Monthly Std .Dev** | **Weekly Mean** ($\mu_d$) | **Weekly Std. Dev** ($\sigma_d$) | **Mean Demand During Leadtime** $\mu_l$) | **Std Dev. Of Demand During Leadtime** ($\sigma_l$) | **Safety Stock** (ss) | **In-Transit Inventory** (It) | |
|---|---|---|---|---|---|---|---|---|---|
| **WT5000 BOARD SUPPLY CHAIN** | | | | | | | | | |
| Lead-time (weeks): | | 8 | | | | | | | |
| Unit Cost | | 105 | | | | | | | |
| WT5000 BOARD | 4138.90 | 4093.40 | 955.87 | 1967.16 | 7646.93 | 5563.98 | 11427.01 | 7646.93 | |
| | | | | | | TOTAL INVENTORY: | 11427.01 | 7646.93 | 19073 |
| | | | | | | TOTAL INV $ | 278590.48 | 186432.11 | |
| | | | | | | TOTAL INVENTORY COST | 465022.60 | | |
| **WT6000 BOARD SUPPLY CHAIN** | | | | | | | | | |
| Lead-time (weeks): | | 8 | | | | | | | |
| Unit Cost | | 185 | | | | | | | |
| WT6000 BOARD | 327.50 | 135.39 | 75.64 | 65.06 | 605.08 | 184.03 | 377.94 | 605.08 | |
| | | | | | | TOTAL INVENTORY: | 377.94 | 605.08 | 983 |
| | | | | | | TOTAL INV $ | 16082.43 | 25746.19 | |
| | | | | | | TOTAL INVENTORY COST | 41827.62 | | |

## MODEM SUPPLY CHAIN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lead-time (weeks): | | 6 | | | | | | | |
| Unit Cost (est) | | 105 | | | | | | | |
| EDGE | 1256.00 | 959.05 | 290.07 | 460.89 | 1740.42 | 1128.94 | 2318.57 | 1740.42 | |
| G20 Dual Band EUR | 1.50 | 6.24 | 0.35 | 3.00 | 2.08 | 7.35 | 15.09 | 2.08 | |
| G20 Dual Band NA | 771.80 | 865.35 | 178.24 | 415.86 | 1069.47 | 1018.65 | 2092.05 | 1069.47 | |
| G24 Dual Band EUR | 1987.10 | 2652.83 | 458.91 | 1274.87 | 2753.49 | 3122.78 | 6413.40 | 2753.49 | |
| G24 Quad Band | 450.00 | 1423.02 | 103.93 | 683.86 | 623.56 | 1675.11 | 3440.26 | 623.56 | |
| | | | | | | TOTAL INVENTORY UNITS: | 14279.36 | 6189.01 | 20468 |
| | | | | | | TOTAL INV $ | 344846.66 | 149464.52 | |
| | | | | | | TOTAL INVENTORY COST | 494311.18 | | |
| | | | | | | Total Safety Stock Cost | 639518.57 | | |
| | | | | | | Total In-Transit Cost | 361642.82 | | |
| | | | | | | **TOTAL INVENTORY COST** | 1001161.39 | | |

# Appendix G

## Summary

| | |
|---|---|
| Cost per WT5000 board | 106 |
| Cost per WT6000 board | 185 |
| Ave Cost per Modem | 105 |

**2007**

| | Current Process | Postponement | Savings |
|---|---|---|---|
| Total Cost of Safety Stock | $724,241.14 | $361,302.09 | $362,939.0 |
| Total Cost of Inv in Transit | $524,924.54 | $245,464.33 | $279,460.2 |
| **Total Cost of Inventory** | **$1,249,165.68** | **$606,766.42** | **$642,399.2** |

**2008 (10mths)**

| | Current Process | Postponement | Savings |
|---|---|---|---|
| Total Cost of Safety Stock | $1,022,105.33 | $639,518.57 | $382,586.7 |
| Total Cost of Inv in Transit | $650,350.55 | $361,642.82 | $288,707.7 |
| **Total Cost of Inventory** | **$1,672,455.88** | **$1,001,161.39** | **$671,294.4** |

**2007**

| | Current Process | Postponement | Reduction |
|---|---|---|---|
| Total # of WT5000 Boards | 24349 | 12828 | 1152 |
| Total # of WT6000 Boards | 1543 | 820 | 72 |
| Total # of Modems | 25891 | 10730 | 1516 |

**2008 (10mths)**

| | Current Process | Postponement | Reduction |
|---|---|---|---|
| Total # of WT5000 Boards | 33175 | 19074 | 1410 |
| Total # of WT6000 Boards | 1651 | 983 | 66 |
| Total # of Modems | 34827 | 20468 | 1435 |

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