

DEVELOPMENT OF REPLENISHMENT AND INVENTORY  
MANAGEMENT PRACTICES

by

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B.S. Industrial Engineering, Purdue University 1996

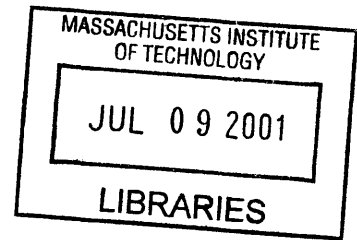
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**BARKER**



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# IMPLEMENTATION OF A REPLENISHMENT PROCESS UTILIZING THE BASE STOCK MODEL

by

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## ABSTRACT

Communication and transparent procedures must translate into robust processes to ensure on-time delivery of components, lower inventories, and a faster response to changing customer demands. This thesis is based on research done at the equipment manufacturing division (HPISM) of Eastman Kodak Company. The focus is on the development of a JIT replenishment process and inventory management practice. The intent of this thesis is to identify critical supply chain characteristics, discuss their implications in determining how to structure a replenishment process, and outline a specific effort to implement a replenishment process back through Kodak's supply chain. Some of the challenges that Kodak faces when designing a new raw material replenishment process include space limitations, demand volatility, differentiating component characteristics, long component lead times, end of life issues, supplier reliability, and operating an MRP bases system in a Demand Flow Technology environment.

Upon studying the supply chain and identifying key characteristics that impact logistics decisions, a general part flow methodology is presented. Utilizing principles of a base stock policy and an "order-up-to" decision system, inventory targets are developed and a preliminary test confirms feasibility. The end result is a framework to guide the design of a JIT/replenishment process.

The impact expected from this thesis is a \$2M reduction of raw material inventory once fully implemented. Additional long-term benefits include improved decision-making processes regarding inventory control, better customer responsiveness, simplified management processes, and lower administrative costs.

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## *CHAPTER 1: INTRODUCTION*

### 1.1 THESIS OVERVIEW

This thesis is divided into three major sections covered in six chapters. The first section introduces the important aspects of supply chain strategy and reviews background information necessary to describe the setting of this research. The second section describes various aspects of the supply chain relative to this study, and the development of a framework used in the design of the replenishment system. The last major section outlines a successful implementation of a test process. It concludes with recommendations and future opportunities.

The focus of this thesis is to develop a JIT/replenishment system at Eastman Kodak Company. A division of Kodak, High Performance Imaging Systems Manufacturing (HPISM), has recently undergone a significant outsourcing effort to focus on core competencies. The goal is to provide a framework which to think about when implementing supply chain initiatives. The context in this case is the development and implementation of a particular replenishment system at Kodak. The themes discussed throughout may be applied to a host of supply chain design and development activities.

Several issues came up during the research that will be discussed in the following chapters. Characteristics that affect the strategy, design, and operation of the supply chain must be considered when designing a raw material replenishment system. The characteristics that affected the design of Kodak's replenishment system are discussed in Chapter 3.

Inventory targets are necessary to provide a foundation for inventory control. A tool that much of the inventory analysis utilized is the Base Stock Model. Briefly, as the model is covered in more detail in Chapter 4, this model calculates strategic stock quantities based on an average and standard deviation of demand, service level, and coverage period desired. Several inventory decision systems are applicable under different circumstances. Those that are relevant to Kodak are described in Chapter 4.

The project team implemented a pilot process that proved to be a success. The technological requirements had been documented but had not been developed. Although a rudimentary



implementation, the success verified the inventory targets and the replenishment methodology. The results were encouraging although there are several issues outstanding.

The thesis concludes with a summary of the research project and future opportunities for Kodak. I also chose to offer some of my reflections on the team process throughout this project. These reflections are based purely on my own thoughts and personal experiences. I offer these reflections hoping to provide insight to assist in the success of similar projects in the future.

## 1.2 TECHNOLOGY EFFECTS ON COLLABORATION COSTS

The rapid adoption of technology over the past two decades is reducing the costs of coordination. The advent of the internet has brought with it speed, ubiquity, and transparency. Communication barriers and transaction costs between business entities have consequently dropped dramatically.

Throughout the 1990's, companies began examining their core competencies and finding other businesses that could manage the non-core competencies more efficiently. Producers and suppliers began to collaborate on order fulfillment according to their respective ability to generate value. There has been an outburst of "supply chain" management activities throughout the entire manufacturing industry. The costs of coordination had sunk lower than the costs of ownership, and the competitive advantage shifted to the networked, value-producing entities that could manage the network most efficiently.

Dell Computer Corporation is one example, often cited as a role model for efficiently managing a networked supply chain. Collaborative inventory-management strategies can reduce stock levels throughout an entire value chain. Michael Dell is driving the development of supply chain strategies to enhance the interactions with suppliers. Many suppliers have on-site planners who manage their own inventory levels on a replenishment basis. Suppliers also have access to such information as daily consumption rates via secured web pages. The result has been shrinking inventory costs and an accelerated cash-to-cash cycle time. Michael Dell has realized the degree to which a higher level of collaboration and information sharing is

needed and is focused not only on improving internal performance, but also the overall performance of the value chain. Dell has successfully incorporated JIT delivery, real-time inventory tracking, collaborative planning, forecasting, and replenishment, while synchronizing supply/demand planning (Joachim, 1998). By providing access to real-time information on production plans, sales orders, and inventory levels, Dell has smoothed the flow of materials and reduced inventory costs throughout the supply chain.

Communication is obviously key enabler in the development of a successful supply chain. Advances in information technology have reduced the costs of coordination, and firms have reacted by disseminating their manufacturing activities to external suppliers whose capabilities are better enabled to deliver that service more efficiently. Firms that have been able to integrate technology into their operating activities and use it to positively effect collaboration within their supply chain have a competitive advantage in being able to execute an effective supply chain strategy.

### 1.3 SUPPLY CHAIN DESIGN AND INVENTORY MANAGEMENT

At the most basic level, two firms interact with one another with the exchange of goods and information. The advent of internet protocols and open architecture systems have increased a firm's ability to pass information accurately and rapidly to its supply base. The better a firm can coordinate and communicate with a supplier, the more nimble and responsive that company will be to changing consumer demands. A major implication that is the amount of inventory held as a buffer between the two entities. Silver and Peterson [1985] report that inventories have an important implication on the financial success of a firm. Typically, they account for 34 percent of the current assets and 90 percent of the working capital of an average company in the United States. Furthermore, the labor costs incurred in the management and control of such inventories can be quite substantial.

Silver and Peterson [1985] suggest five broad decision categories for controlling aggregate inventories: cycle stock, safety (buffer) stock, anticipation inventories, pipeline inventories, and decoupling stock. A firm must consider all aspects of inventory management. However, this thesis is primarily focused on developing inventory targets for cycle and safety stocks. To

appropriately minimize the need to carry on hand inventory, this project also involved developing an order/receipt process to implement such targets.

The design of a supply chain, even more specifically, the replenishment process, can affect both the cycle stock and the safety stock a firm needs to hold in inventory. A design that effectively minimizes the costs of ordering raw material, and enhances a supplier's ability to reduce the uncertainty in the lead times will result in minimal cycle and safety stocks in on hand inventory. Those firms that can take advantage of recent technological advances and incorporate their suppliers into a "virtual entity" operating essentially as one unit, will be most successful maximizing service with minimal inventory stocks.

## CHAPTER 2: PROJECT DESCRIPTION

### 2.1 PROJECT MOTIVATION

Historically, Kodak has chosen to maintain a vertically integrated manufacturing strategy with its product lines. An initiative took place in 1998 to evaluate Kodak's manufacturing operations' relative to fit with its strategy and core set of competencies. Several manufacturing operations were outsourced as a result. The outsourcing was performed quickly to meet aggressive goals causing several business units to experience supplier reliability problems. The manufacturing exodus cleared several million square feet of space within Kodak's Elmgrove facility. As this research began, the Elmgrove facility was utilizing approximately one-fifth the space available.

This thesis project was necessitated by a top management decision to consolidate manufacturing facilities. All business units located in Elmgrove are to be relocated within the realm of Kodak Park near the paper and film manufacturing division. Manufacturing space at the new facility is drastically reduced. In particular, the space set aside for raw material storage is one-third the current size. Such a drastic reduction in space forced the HPISM organization to consider operating alternatives to accommodate this change. Several methods exist for managing inventory, such as MRPII, stock level pull systems, and vendor-managed inventories. This research attempts to solve the problem above by evaluating the supply chain characteristics, identifying operating alternatives, and working to implement solutions.

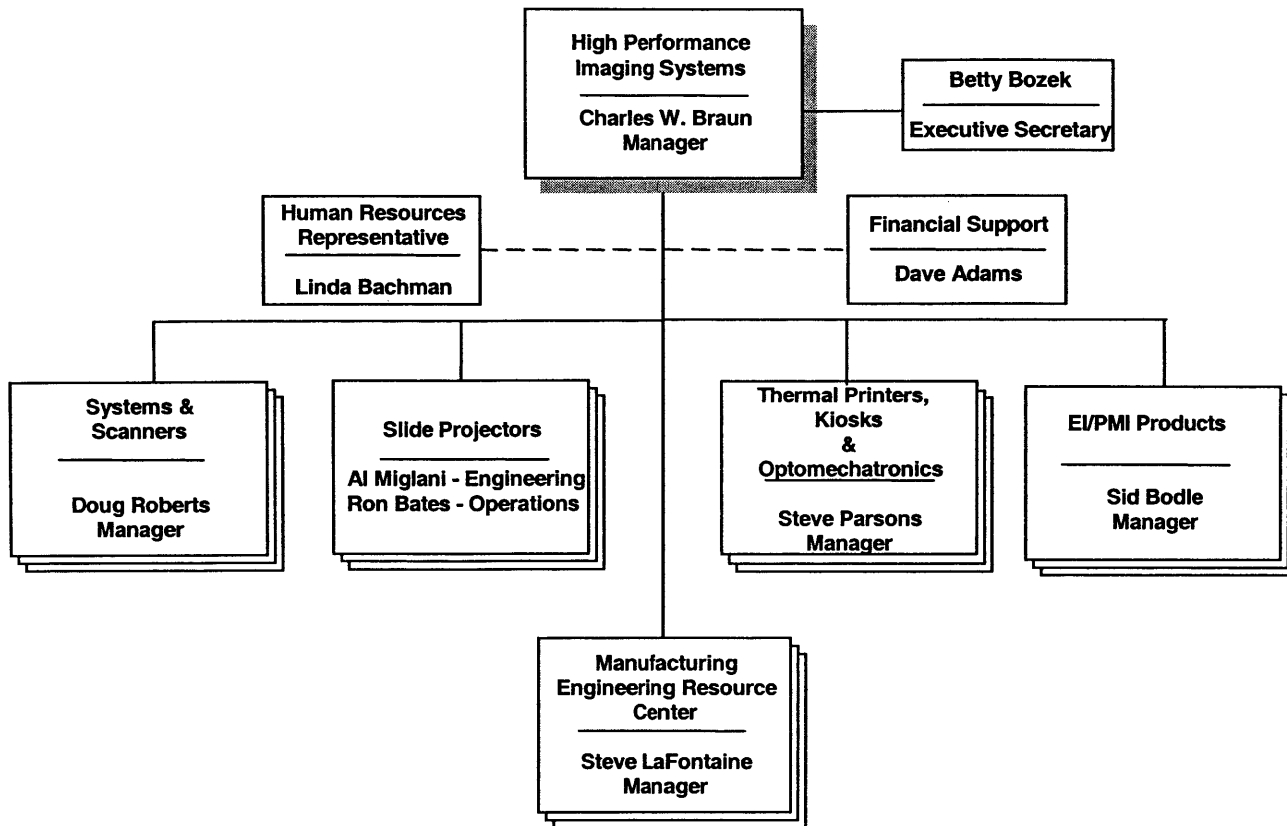
### 2.2 INTERNSHIP SETTING

High Performance Imaging Systems Manufacturing (HPISM) is part of Kodak's Equipment Manufacturing Division. HPISM manufactures several products including thermal printers, kiosks<sup>1</sup>, digital cameras, slide projectors, and large photofinishing equipment. An organizational view is given in figure 1 below.

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<sup>1</sup> Kiosks are comprised of wooden cabinetry, a scanner, monitor, processor, thermal printer, and peripherals that allow consumers to scan, print, upload and share digital pictures over the internet.

**Figure 1. HPISM Organization**



My vantage point from within the organization was from thermal printers, kiosks, and optomechatronics manufacturing group, reporting to the business unit supply chain manager. The analysis was more specific to this group, although, throughout development, the implications to all other affected business units were also considered. Other BU's include Systems & Scanners, Slide Projectors, and EI/PMI Products.

The core team consisted of supply chain managers from each BU. The team champion was the site supply chain director. Extended team members included buyers from each BU, commodity managers, and stock vault personnel. The team leader was on special assignment, assigned to this role from a logistics manager position.

## 2.3 PROBLEM DESCRIPTION

The project team must design and implement a single business process by which all four BU's can abide. The process must also accommodate the two-thirds reduction in raw material space. The process must consolidate all receiving, stocking, and picking activities of the business units into a central vault location. The success or failure of this implementation would largely rest on the ability to overcome several complicating factors.

### Independent Business Units

One major challenge is overcoming the fact that all four business units act independent of one another with legacy workflow processes. One supplier may be interacting with and accommodating several different BU's at Kodak, each with a different process. Each BU has its own method to order, receive, store, and pick material that has been developed to suit a specific product line. In addition, at the time of this project, these BU's were just transitioning to a common MRPII system - Fourth Shift<sup>2</sup>.

### Inventory Control Procedures

Another issue is the lack of adherence to an inventory policy. Kodak did use an A-B-C<sup>3</sup> categorization method, however buyers rarely have time to truly manage inventory levels. Much of the buyer's time is utilized "fighting fires" and figuring out which orders to pull in or push out. Their main objective is to ensure parts are available for production. Consequently, inventory policies tend to be "soft" and the levels are managed individually more by instinct. Such a system will not succeed in a demanding environment such as JIT. The speed at which material moves through a JIT system is too fast to manage in such a manner. HPISM puts significant effort towards inventory reduction, yet these efforts are often difficult to evaluate because inventory targets have not been matched to customer demand. Without formal methods and models that reflect the dynamics of the demand stream, it is impossible to assess the impact of operational improvement with respect to inventory levels. The new replenishment system will have to address this issue of inventory management.

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<sup>2</sup> An MRPII system developed by the Fourth Shift Company and used by most business units in HPISM.

<sup>3</sup> A common classification system that assigns a priority rating to each and every s.k.u. in inventory according to its value. It is common to use three priority ratings: A (most important), B (intermediate in importance), and C (least important).

### Product Variety

The product variety and resulting supply chain complexity pose a challenge as well. Products across these business units have a diverse set of characteristics. As the array of supply chain characteristics and part complexities becomes wider, the more robust the process must be to handle the different situations. The challenge is maintaining the right balance, and the simplicity of the overall system, when creating different logic for different products.

### Supply Chain Power

HPISM exerts less power and influence over its supply chain than that of Kodak's traditional paper and film business. In this instance, it becomes increasingly necessary to open communication and information channels focused on automating manual processes and reducing transaction costs on both sides. Forecast accuracy is another source of concern. Unless a supplier is operating in a JIT delivery environment, implementing the replenishment process requires the supplier to hold finished goods inventory. The costs may be offset by the ability to better plan production. Suppliers can utilize the actual demand/usage information to augment their planning process. Suppliers must be convinced that their net benefits from the system are positive. Our task was to design the processes to be robust and transparent, thereby increasing the power and efficiency of the overall supply network.

## 2.4 PROJECT SCOPE

The new business process will affect several aspects of each business unit – planning, buying, receiving, stocking, and picking. At a minimum, the team will need to gain organizational “buy-in” from twenty functional units. Furthermore, suppliers are affected quite drastically. This necessitates their upfront involvement and that of Kodak's commodity management group as well.

Work peripheral to the core mission of the project was also performed. Other activities included supplier development and quality management, both of which would have a significant impact on the success of the project. The steps followed during the development of the framework are as follows:

1. Understand supply chain characteristics that affect process flows and logistics
2. Develop appropriate method to model inventory and set stocking targets
3. Work with suppliers to discuss requirements and garner support for new process
4. Implement test of process methodology utilizing current technology
5. Identify improvement opportunities
6. Evaluate results



## CHAPTER 3: PART FLOW METHODOLOGY

Transportation and logistics costs must be considered in the design of the replenishment process flow. These costs are often the determining factor when making supply chain decisions. Toyota has suppliers located next to its manufacturing to minimize the impact of transportation costs on operating profit. The reduced coordination costs between Toyota and the supplier justifies the facility investment costs. The following chapter identifies the cost tradeoffs that we considered when developing the new part flow methodology.

### 3.1 SUPPLY CHAIN ATTRIBUTES AND EFFECTS

Different supply chain attributes affect the design of process flows in several ways. For example, items stored in inventory can differ in size, shape, cost or volume. Units may be stored in a number of ways as well - in crates, cardboard boxes, on pallets, or loose on shelves. Suppliers may supply one part number or hundreds of components and may be local or long distance. All of these attributes can affect the way in which a replenishment system operates because they all, in one way or another, have an impact on the cost of the overall system. When designing the over-arching logistic methods, the impact of local vs. distant suppliers, packaging size, and suppliers that supplied many vs. just a few components are considered. These attributes had an affect on the framework developed to accommodate a common process across all business units.

Supplier proximity plays a key role in designing the material flows and guiding processes that govern a replenishment system. It is easier to coordinate deliveries with a close supplier. In addition, more options are available with respect to process design and inventory management. Furthermore, there is much less uncertainty in lead-times and replenishment periods for local suppliers as opposed to deliveries traveling hundreds or thousands of miles. Delivery frequency can increase with local suppliers without as large a cost impact. Options for delivery include direct ship, use of a hub, or a “milk-run” type of operation, any of which can be incorporated if a supplier is local. A milk-run operation refers to the analogy of a milkman making deliveries and picking up empty milk bottles in a designated delivery area. HPISM

would use a third party logistics provider to pick up orders at local suppliers and make daily deliveries to its manufacturing facility. Local suppliers reduce the implications of the other two considerations, packaging size and number of components, because of the lower cost and ease of transport.

The amount of capacity used in the transportation vehicle heavily impacts the cost of delivery. A firm's ability to realize the cost advantages associated with full truckloads is dependent upon three primary factors:

1. frequency of delivery (hence, the amount of an average order)
2. packaging size as it relates to overall truck space
3. number of other components that can be consolidated on the same truckload.

### 3.2 OLD PROCESS FLOW

HPISM schedules orders using a typical MRPII type methodology with a few exceptions. Orders are pushed into the system from an exploded bill of materials based on an end item master production schedule. These orders are centrally managed by buyers who reside in the business units. Different buyers manage inventories with slightly different methods. Some adhere, at least in part, to suggested A-B-C inventory levels, while others manage inventory levels based more on intuition. Buyers across different business units have developed a sense of intuition about how much inventory to hold at a part level. Their particular method varied due to issues like reliability, quality, responsiveness, and other historical problems the buyers may have experienced. Buyers are often forced to manage inventories on the fly as the dynamic nature of production forces schedule changes that impact delivery schedules. The majority of a buyer's time is spent ensuring material availability while appropriate inventory levels take a distant secondary priority.

Kodak has designated a short list of consolidated carriers for their suppliers to use for shipping. The carriers pick up the order(s) at the supplier and truck the order(s) to a central warehousing facility where they cross-dock. All Kodak orders are consolidated before shipping to the Kodak facility. Suppliers deliver directly to Kodak with their own trucks in situations where

orders are being rushed or when an alternate system such as JIT is practiced. Also, several local suppliers are able to gain sufficient scale economies with respect to a full truckload such that they could deliver direct to the Kodak facility as well.

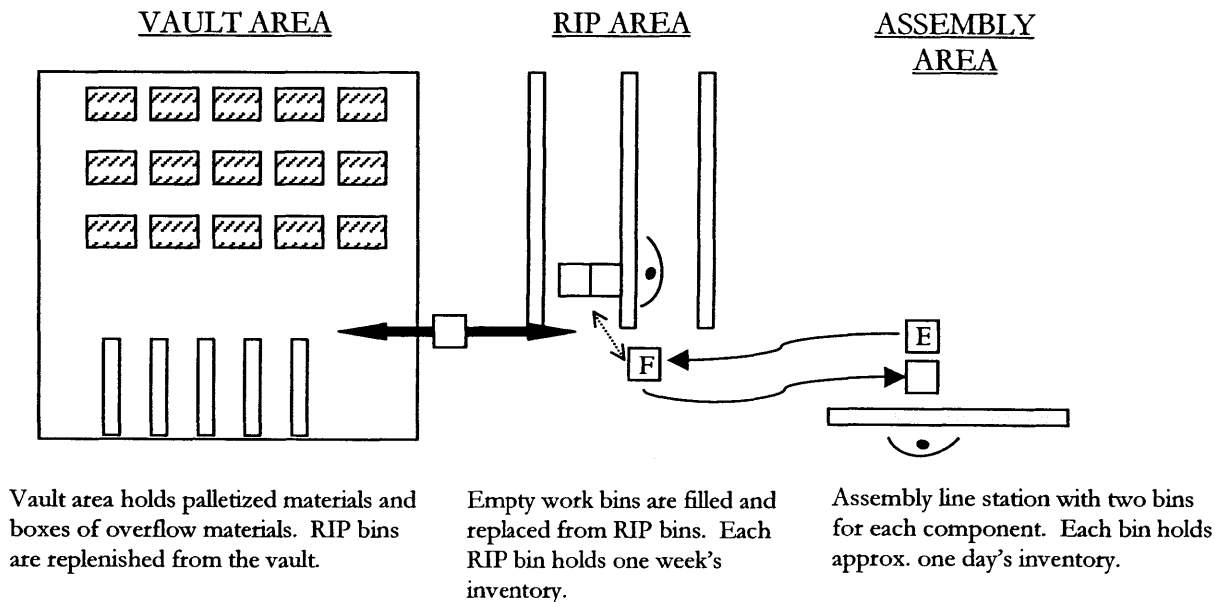
In spot situations with certain assemblies, suppliers are on a JIT replenishment system already. For example, the roller mechanism assemblies in the thermal printers are delivered direct to Kodak on the cart used in the assembly area. The carts serve as the kanban signal when empty and instruct the supplier to take the empty cart back. Once full with another load of assemblies, another delivery is made. These instances are more an exception than a rule.

The receiving and stock processes vary across the business units as well. Each business unit has its own dock, stock vault and receiving personnel. Each operation essentially acted independent of one another. At the core of most processes however, was a “two-bin” system of inventory management for small-medium sized items. Two bins are located at the workbench for workers to pull from. Each bin holds approximately one day’s material. As one bin is emptied, it is sent back to the “RIP” area to be re-filled. The RIP area is an intermediate stocking point, also operated on a two-bin system. Each RIP bin holds approximately one weeks’ worth of material. As a RIP bin is emptied, it is placed on a cart and returned to the vault to be re-filled. The vault is the main storage area for raw material that is stored on shelves and/or pallets. In overstock situations, overflow from the shelf location will remain in palletized condition. Once the backlog is reduced, material will be transferred from the pallet to the shelf and eventually to the assembly floor. The vault personnel pull stock from the vault shelves to fill the RIP bin and return the full bin to the RIP area. See figure 2 below.

The current material flow allows up to four locations of inventory. In an overstock situation, stock may move from a pallet location, to a shelf, to the RIP, and finally to the workbench. Although an overstock situation is an exception, the normal three levels of inventory are also excessive. The additional material handling and planning complexity is unnecessary. Absent of any value-added steps between the vault and the RIP, resources should not be consumed to move and track materials between these storage locations. The resulting impact on planning is significant. Raw material in the RIP is considered work-in-process (WIP) and part of floor inventory. On-hand inventory is debited when material is transferred from the vault to the RIP.

This quantity of material is then lumped with WIP inventory level as seen by the planners. In order to get an accurate number of parts actually available for production, it requires a manual count of parts in the RIP area and at the workbench.

**Figure 2. Material Stocking/Replenishment Flows**



Other business units have altered the process in different ways. For example, one has eliminated the RIP area all together and bumped up the quantities stored at the workbench on the assembly floor. It is important to note, however, that in all cases it is still the MRPII system and the buyer that trigger the delivery of parts from the supplier. An empty bin is only used *internally* between the shop floor and vault personnel to signal the need for parts. In a perfect system, the receipt of parts will match the appearance of an empty bin at the vault location. Furthermore, the order quantity would equal one bin worth of material. In reality, because of incomplete and delayed information, or variability in supplier lead times and reliability, this match rarely occurs. Rather, the buyer is constantly battling early deliveries and rushed orders.

Large parts that are stored on pallets deviate from the system previously described. They are stored in a palletized vault location and brought directly to the assembly floor as needed. Buyers manage the orders via “on-hand inventory” showing in the MRP system and the intuitive level of stock that they have determined appropriate.

Two basic material flows exist as incoming orders are routed to their designated holding locations.

1. Receiving → Rapid-fire → Assembly (JIT and “hot” parts)
2. Receiving → Vault → RIP

Material may be routed through rapid-fire direct to the assembly floor, or through the vault. Rapid-fire served as a temporary holding area for JIT and “hot” parts needed immediately. Normally these parts would remain in the rapid-fire area less than ½ day. Over time the rapid-fire area became the designated location for several part numbers, most of which were large palletized items that would turn rapidly. If rapid-fire were full, then these parts would be stocked in an inventory position on a vault rack. The majority of the material does not go to rapid-fire but enters the vault area for further processing. Vault personnel check to see if a RIP bin was waiting for the incoming material before assigning a vault location.

When supplier coordination is high, incoming material can be timed to match the emptying of a RIP bin. Effective timing eliminates the non-value added transfer between the vault and RIP areas. The new logistics process must accommodate frequent deliveries with smaller order quantities. Much of the remainder of this thesis is devoted to creating a new logistics process and setting inventory targets.

### 3.3 NEW PART FLOW METHODOLOGY

There are two aspects to the new part flow methodology – the inbound logistics, and the internal material and information flow. It is desirable to bring as much as possible directly into the floor or RIP area and avoid overflow situations. The vault would be used on a limited basis

for large, palletized items. The new process will eliminate the vault-to-RIP transfer. There are three aspects to our approach. First, the inbound logistics process must accommodate increasing inventory turns and minimal on-hand inventory levels. Second, appropriate inventory targets must be in place to minimize the need to store materials. Lastly, communication processes must be set in place to trigger the delivery of additional parts. The first aspect is discussed in the following paragraphs, and the latter two are discussed in the following chapter.

Several factors affect the inbound logistics process. The degree to which each business unit is affected by a particular factor varies. Based on observations and discussions with the replenishment team, the factors with the highest degree of impact relative to incoming logistics are as follows:

1. Supplier proximity
2. Ability to fill truckload
3. Number of parts supplied (many vs. few)
4. Part size

The implications of these attributes have an effect on the degree to which coordination is desired. Supplier proximity is particularly important in that for all local suppliers the transportation economics are less of a factor. It is feasible to implement a milk-run system, and generally more adaptable with regard to cost. Part size is a critical factor in determining the internal material flow of that part upon receipt at the Kodak facility.

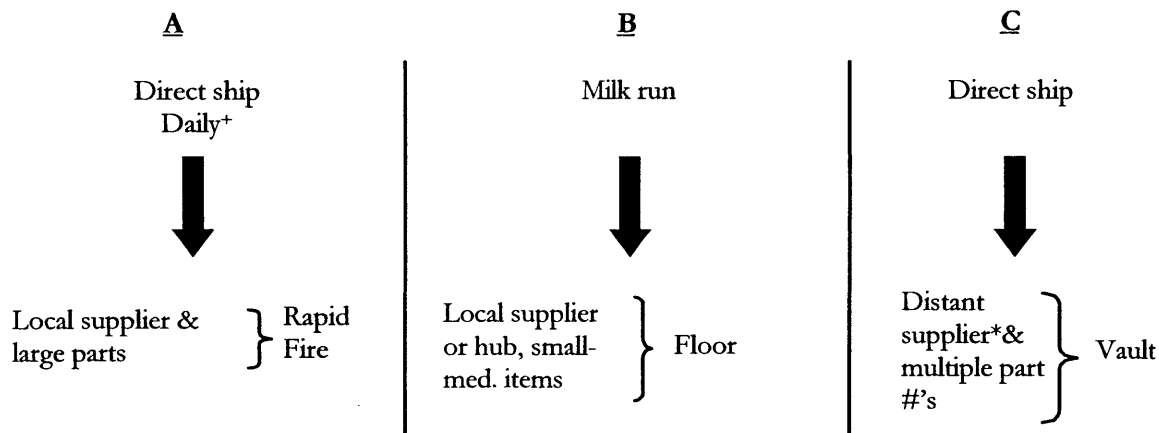
Some items such as large OEM components for kiosks (scanners, monitors, processor, etc...), it will be necessary to store components in the vault area primarily due to transportation costs. These items are typically one of only a few items from that supplier. To maximize transportation efficiencies, it is necessary to order full truckloads and hold the excess inventory in the vault. In the next section, a “hub” model will be discussed as a potential method for alleviating the burden created by the transportation costs in this example.

Multiple part numbers are often shipped from the same supplier. In this case, coordination of replenishments is attractive to reduce unit transportation charges. Significant efficiency can be

realized by sharing the same transportation mode. However, storage costs will be incurred resulting from the consolidation of products onto the same shipment.

Better communication and logistic processes reduce the need to carry inventory. The majority of benefits in this sense would result from HPISM’s large, local supply base. Items from local suppliers may be assigned different process flows based on the size of incoming material. For large items, several deliveries per day and low variability in delivery lead-time make it possible to route these parts through the rapid-fire area, introducing them to the assembly floor in a matter of hours. For smaller sized items, a milk-run will achieve the service level needed in a just-in-time environment. Coordination will be built into the milk-run system to allow several suppliers to share logistics costs. It is anticipated that a third party logistics provider will designate specific trucks to make Kodak specific routes based on a daily electronic “pick list” provided from Kodak. This process eliminates the delay associated with cross docking at the consolidated carrier’s distribution center. The order will be triggered by electronic signal to both the supplier and the trucking company so that both know a delivery is needed. A summary of these flow methodologies can be reviewed in Figure 3 below.

**Figure 3. Part Flow Methodology**



\*To minimize space, distant suppliers w/ large parts should use local Hub and deliver daily

### 3.4 HUB ALTERNATIVE

The use of a hub, exemplified by Dell Computer Corporation, was also considered as an option for creating a local supply origin for distant suppliers. Our discussions in regards to the use of a hub began to develop shortly before the end of this research. Some considerations are relevant to the success or failure of such a system and need to be discussed.

Dell's implementation of a hub consists of a local warehouse storing supplier-owned inventory. All suppliers ship to Dell via the hub. Hourly deliveries are triggered by a sophisticated IT system. Products are consolidated onto a truck and delivered to Dell just-in-time. Dell has been able to refine this process to an extent that virtually eliminates all raw material from its books.

HPISM's supplier leverage is less than that of the computer giant, however many of the benefits the hub offers are desperately needed. Most impressive is Dell's ability to influence suppliers to maintain ownership and manage inventory at the third party warehouse. At the conclusion of this research, it was seemed doubtful that Kodak's suppliers would be as willing to do so. OEM's for monitors, scanners, and processors are a prime example. These companies are extremely large and the quantity of Kodak's business, although significant, does not warrant the same partnership as with Dell.

While the use of a hub would increase handling and therefore costs, the necessity may prove unavoidable. Many of the distant suppliers (such as OEM's) ship parts extremely large in size. The hub essentially makes these suppliers "virtually local" in terms of the JIT delivery logistics. It also reduces the significant amount of vault space necessary to accommodate these items. One week's supply of just the wood, plastic, and OEM components for kiosks requires approximately 20% of the available pallet space at the new facility.

Kodak currently uses and subsidizes a hub for the paper and film businesses. The operations of the existing hub were under development and in the process of being transferred to a third party. Despite this research coming to an end just as discussions about the hub were picking up, my research and space estimates indicate the hub is a necessity, at least in the short term.



To ensure a successful transition and continuing operations in the short-term, the hub should be used.

### 3.5 SUMMARY

The new part flow methodology minimizes the storage of raw materials in the vault area. Three flows were created after examining critical part and supplier characteristics. The size of a part, truckload shipments, array of parts supplied, and the proximity of the supplier all play crucial roles in determining the appropriate incoming material flow process for each part. Re-evaluating the incoming material processes was necessary but not sufficient for achieving our project goals. In the next chapter, decision systems related to inventory management are discussed. Inventory targets are then developed using a periodic review, base stock policy.

## CHAPTER 4: NEW REPLENISHMENT PROCESS

Inventory systems are at the core of any replenishment process. This chapter describes the recommended method that HPISM use to set and control inventory targets. There are many books on the subject that go in depth about many different types of decision systems for inventory control. Most start with the simple economic order quantity (EOQ) and progress to more realistic models by relaxing the assumptions associated with the EOQ. In the context of this project, it seemed most appropriate to use a probabilistic demand model operating based on a periodic review, base policy. This type of model best matches the parameters associated with HPISM's operation.

1. The demand rate varies over time, however the average demand remains relatively constant.
2. The order quantity needs to be an integral number of units with minimum sizes equal to the package size.
3. Most items can be treated entirely independently of other items. However, in some glaring instances like suppliers delivering multiple part numbers (i.e. wood), savings in the unit transportation cost can be realized through replenishment coordination
4. The replenishment lead-time is known with reasonable certainty.

### 4.1 PERIODIC REVIEW, BASE STOCK POLICY

The periodic review, base-stock model implies that an authorized buyer will trigger demand for an order upon reviewing the current stock situation over regular time intervals (for example, all items from the wood supplier would be reviewed and ordered every Thursday). A review interval ( $R$ ) represents the time that elapses between moments at which the inventory position is known. Significant uncertainty may exist as to the value of the stock level between reviews. In contrast, stock status is always known with a continuous review. The main advantage is that less inventory is required to provide the same level of service. However, it is often much more expensive in terms of reviewing costs and errors (Silver and Peterson, 1985). There is incentive for operating a periodic review policy for items that might benefit from coordination. This was the instance considering the wood supplier for Kodak's kiosk line. It was attractive to

Kodak to coordinate the replenishments by consolidating the review of all wood parts (from this particular supplier) to Wednesdays. Assumptions for the periodic review system that follows include (Morrison, 2000):

- review periods are constant, R
- replenishment lead time is known, L
- demand occurs in non-overlapping time intervals
- demand between parts is independent
- an order is placed after each review cycle

The control system suggested as a result of this research is a periodic-review, order-up-to level (R,S) system based on end item consumption. End item consumption is examined during the review period (R). An order is placed after each review to bring the inventory position back to a sufficient level (S), also known as the order-up-to point. If sufficient changes in demand have occurred since the last review period, the order-up-to point can be adjusted. This is particularly appealing in situations when the demand pattern is changing over time. S is often viewed as a theoretical maximum inventory position. However, the inventory level S includes both on-hand and on-order inventory. On-hand inventory will not actually reach the order-up-to level due to the consumption of parts during the replenishment lead-time. Figure 4 represents a graphical interpretation of the periodic review cycle.

$$S = \text{on-hand} + \text{on-order inventory} \quad (1)$$

The inventory position S must be sufficient to carry production through both the next review period R, and replenishment lead time L.

#### 4.2 COMPONENTS OF INVENTORY

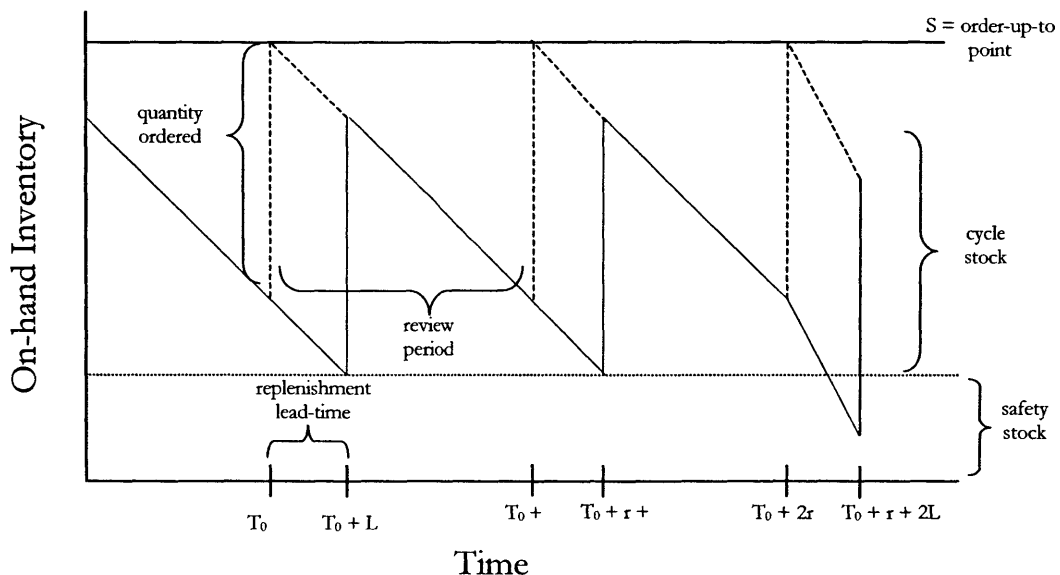
Silver and Peterson [1985] recommend five decision categories for controlling global aggregate inventories: cycle stock, safety stock, anticipation inventories, pipeline inventories, and decoupling stock. The terms are defined in Table 1.

**Table 1. Definitions of the Components of Inventory**

<b>Cycle Stock:</b>	The amount of inventory on hand, at a given moment, that results from an attempt to order or produce in batches.
<b>Safety Stock:</b>	The amount of inventory kept on hand, on the average, to allow for the uncertainty of demand and supply in the short run.
<b>Anticipation Inventories:</b>	Stock accumulated in advance of an expected peak in sales
<b>Pipeline Inventories:</b>	WIP inventories between levels of a multi-echelon system or between adjacent workstations on an assembly line
<b>Decoupling Stock:</b>	Strategic stock placed in multi-echelon systems that allows for decentralized decision making at different echelons

Anticipation stocks are not considered in the replenishment model, as sales are assumed relatively stable. Pipeline and decoupling stocks are precluded because the replenishment model is based on a local optimization as opposed to a multi-echelon system. There are two components of direct importance to this project – cycle stock and safety stock. The cycle stock covers an average level of demand between replenishments. Safety stock protects against variability in demand over a designated coverage period. See Figure 4.

**Figure 4. Periodic Review Cycles**



### 4.3 INVENTORY TARGETS:

A simplified base stock equation from Graves and Willems [2000] calculates the order-up-to level as follows:

$$S = \mu_D(R + L) + z\sigma_D\sqrt{R + L} \quad (2)$$

Where  $S$  = the order-up-to point, or inventory available over coverage period

$R + L$  = coverage period, or review interval + replenishment time

$\mu_D$  = expected demand over single coverage period

$\sigma_D$  = standard deviation of demand over single coverage period

$z$  = service level or safety factor

In computing the value of  $S$ , it is necessary to assume that  $R$  is predetermined. Applying this model at Kodak, we were less concerned about the economics of carrying costs and more concerned with the space constraint. To minimize expected on-hand inventory, I chose to intuitively determine approximate value for  $R$  based on the dynamics of the supply chain. Again, the wood provides a good example. One week of production necessitates approximately one truckload of wood in aggregate (consisting of many different part numbers), so  $R$  is set equal to one week. The review frequency can be increased to two times per week with implicit cost trade-offs from transportation efficiency losses.

#### Calculating $\mu_D$ and $\sigma_D$ :

I consulted the supply chain manager to decide the best method to approximate  $\mu_D$  and  $\sigma_D$ . Forecasts are commonly used but we wanted to link replenishments directly to actual production. The dynamics of kiosk and thermal printer forecasts yielded a poor representation of expected demand. After some discussion, we decided to use historical data to approximate future production rates. Demand was relatively constant over short periods, but the production manager wanted an aspect of the model to include planned production rates in case of a ramp up. We felt that eight weeks of historical production averaged with four weeks anticipated production would provide the needed balance between demonstrated production and future plans.

### Safety Stock:

$$z\sigma_D\sqrt{R+L} = \text{safety stock to cover variation over period } R + L \quad (3)$$

where  $z$  = safety factor corresponding to level of service (Graves and Willems 2000).

The choice of  $z$  represents the percentage of cycles that safety stock covers the demand variation. It may also be interpreted, as how frequently expediting tactics will have to cover the demand variability. Other service level measures may include percent of demand satisfied from stock. Safety stocks do not have to be based on service considerations. Many other criteria may be used to establish safety stocks of individual items. Silver and Peterson [1985] list four alternatives.

1. Safety stocks established through a common safety factor – this approach usually involves a common time supply of safety stock across items. This approach is quite common despite a major flaw. The policy doesn't take into account the variation in demand uncertainty from item to item.
2. Safety stocks based on the costing of shortages – this technique requires a method to cost shortages based on some known characteristic (for example, number of backorders). The difficulty in this approach is associated with assigning a proper cost to a shortage situation. At Kodak, the accuracy of any costing method fails to make this a reliable and accurate technique.
3. Safety stocks based on the effects of disservice on future demand – this method makes future demand a direct result of the service now provided. This approach intuitively makes sense particularly in businesses that have a strong repeat customer base. It is however, very difficult to translate the conceptual model to an appropriate functional form.
4. Safety stocks based on aggregate considerations – this approach establishes individual safety stocks up to an allocated quantity that meets a desired aggregate service level

The choice to use a method based on service considerations recognizes the difficulties associated with the methods described above. There are also many alternatives when choosing

the type of service consideration. Our choice was based on the established environment at Kodak and management's definition of "service."

Common service levels and corresponding z factors are given below

<u>Service Level Desired</u>	<u>z-Factor</u>
99%	3.00
98%	2.00
95%	1.64
90%	1.28

It can be shown that the expected on hand quantity (assuming the mean rate of demand is constant over time) is as follows:

$$E(OH) \cong z\sigma_D\sqrt{R+L} + \mu_D(R)/2 \quad (4)$$

We have assumed all along that the replenishment lead-time  $L$  is known. If  $L$  is not known, then safety stock must be incorporated to account for this additional uncertainty. Choices among transportation modes and distance traveled can affect the variability of the transportation lead-times. The following is used determine the standard deviation of total demand during the transportation lead-time (Silver and Peterson, 1985).

Let  $L$  = replenishment lead-time, in weeks

$D$  = Demand rate, in units/wk

$L$  and  $D$  are assumed independent random variables.

$$E(x) = E(L)E(D) \quad (5)$$

and

$$\sigma_x = \sqrt{E(L) \text{var}(D) + [E(D)]^2 \text{var}(L)} \quad (6)$$

where

$x$ , with mean  $E(x)$  and standard deviation  $\sigma_x$  is the total demand in a replenishment lead-time.  
 $L$ , with mean  $E(L)$  and variance  $\text{var}(L)$ , is the length of a replenishment lead-time.  
 $D$ , with mean  $E(D)$  and variance  $\text{var}(D)$ , is the demand rate.

Simply substitute  $\sigma_x$  in place of  $\sigma_D \sqrt{R+L}$  in equation 3 to calculate the revised safety stock necessary to account for the variation in transportation lead-time.

#### 4.4 VALIDATION MODEL

It was necessary to ensure that the review periods assigned to various part numbers would result in a satisfactory solution to the HPISM's space problem. A simple spreadsheet model can provide a method for modeling the utilized space given a scenario. The order-up-to quantity is split into cycle and safety stock. If the pallet densities for each part are known, it is possible to model the total space required.

Assuming parts are independent and the  $E(OH)$  quantity is randomly distributed, the total pallet space needed can be expressed as the sum of the individual  $E(OH)$  quantities multiplied by the corresponding pallet density ( $\rho_i$ ).

$$\text{Total pallet space needed} = \sum E(OH)_i * \rho_i \quad \text{for all parts} \quad (7)$$

where  $\rho_i$  is the pallet density for part  $i$   
and  $E(OH)_i$  = expected inventory for part  $i$ .

A sample portion of this spreadsheet can be seen below.

**Figure 5. Validation Spreadsheet Headings**

Part Number	$\mu_D$ / wk.	$\sigma_D$	Review Period (R)	Service Time (L)	Service Level (z)	Cycle Stock (parts)	Safety Stock (parts)	E(OH) (parts)	Pallet Density (parts / pallet)	Space req'd (pallets)



The success of the model is based on the assumption that a stock of finished raw materials exists at the supplier site or a hub location. If this is not the case, replenishment lead-times must also include manufacturing lead-time. The effect would increase the order-up-to level and push the total inventory beyond the constraints of the new facility. Replenishment time  $L$  is equivalent to the time it takes a supplier to recognize an order, pick, pack and ship the product. It also includes the delivery time prior to receiving the product at Kodak's facility. The order point  $S$  should cover demand during  $R + L$  with high probability.

#### 4.8 SUMMARY

Inventory targets are critical in any inventory management system. A method to evaluate inventory levels is necessary to provide a basis for logical action. I presented in this chapter one of several available means to developing inventory targets. The choice to use the "order-up-to" decision system was based on the specific circumstances surrounding the HPISM organization.

## CHAPTER 5: IMPLEMENTATION

### 5.1 TECHNOLOGY CONSIDERATIONS

Technology is a critical consideration in designing the control and communication systems of the replenishment processes. There are so many options with varying complexities that may be adopted as IT enablers. The technology solution must make procurement processes easier, speed the communication process, and facilitate inventory management decisions. At the end of this research, the technology decision had not yet been made. It is important however, to discuss the approach and technology under consideration during this project.

HPISM's procurement process was a manual process with communications happening over the phone, fax, or email. In a few instances, suppliers were connected via EDI and received automated ordering information. A major problem with EDI is the need for dedicated "pipe" to the supplier. If a supplier was to be added to the EDI process, a significant amount of IT work and money was involved to get that supplier "hooked up." EDI is therefore expensive to implement and not very flexible to scale. Web-based solutions offer the flexibility and scalability needed, however the costs are also somewhat prohibitive given the local nature of this project. Our team decided to create our own solution.

In order to track the quantity consumed between replenishment cycles, we utilized best practices of another division within Kodak. Barcoding technology is being utilized in another part of the company to track the flow of inventory and trigger an automatic order when appropriate. The system integrates directly into the MRP system, Fourth-Shift, and eliminates the labor-intensive, manual transactions. The algorithm behind the program is able to track part usage as parts are removed from the vault inventory. At the end of each review period, the inventory position is reset to the order-up-to point by an order sent via email automatically to the supplier. The supplier is expected to acknowledge the email upon receipt and communicate any difficulties in satisfying the order within the agreed upon replenishment lead-time. Upon receipt at the Kodak facility, the order is scanned and the inventory automatically updated in the MRP system.

One essential component that was missing at the conclusion of my internship was an open architecture system that provides a method for suppliers to gain access to real time inventory information. This ability offers the supplier a method of verifying the forecast information and making appropriate adjustments in its production. The absence of this particular feature introduces a delay in the reaction to unforeseen spikes in demand. Conversely, an inventory build-up may result if demand slows unexpectedly.

## 5.2 OUTSTANDING ISSUES

This project ended six months prior to the scheduled date to move into the new facility. Many open issues need to be resolved prior to implementation. Due to the unresolved nature of these issues, I have very limited and preliminary information and will therefore touch only briefly on the status and nature of these challenges at the end of my internship.

Supplier agreements were absent in most cases regarding replenishment lead-times and service levels. In many cases, supplier reliability was inconsistent at best. Any sort of JIT process is likely to fail in the presence of poorly performing partners. In order for this process to work successfully it will be necessary for most suppliers to increase the amount of finished goods at their facility. Furthermore, cost implications resulting from this still need to be negotiated.

The degree to which inventory targets had been determined was very limited. Much more work was needed in determining the appropriate review period for each part. Furthermore, supplier commitment to hold finished inventory was spotty. Without a guaranteed finished goods inventory level, the variation in replenishment time will prove unbearable under the circumstances. The project team was concerned about the time necessary to review data associated with each part to determine individual part targets. To resolve this issue, the team was discussing setting all “A” part targets to a standard two-week supply.

The development of the bar-coding technology had not begun and thus not been tested. The hardware decision and the algorithms for the decision systems were still required. The firm that was chosen to do the development had extensive experience with Fourth Shift and could easily integrate the two systems.

The model assumed a constant average demand rate. This assumption is subject to fault. A review process needs to be in place to update inventory targets as business improves or declines. Morrison [2000] suggests a possible solution is to control chart the safety stock at the time an order is received. If the target level has been chosen appropriately, the x-bar chart should yield an average inventory value equal to the safety stock. This is a simple process that could be incorporated into the bar-code program.

To properly utilize the principles and framework I described, it is necessary that people involved in the process be trained on the underlying principles as well as the actual operating model. Towards the end of my internship, I completed a working spreadsheet and instructions describing the dynamics of the model. I spent an afternoon training the purchasing personnel in the thermal printer & kiosk group. However the other groups should also be trained on the proper use and principles of the model.

There had been no resolution to whether or not the use of the hub would be an alternative for material storage. Discussions with Kodak's hub management were just getting under way, so the operational and logistic details were still a bit unclear. Suppliers are most concerned about the additional costs, and whether they are expected to bear the burden. The costing methods used at the hub facility were being re-evaluated and most likely will be changed to an activity based costing system.

Finally, the third party logistics issue had not been broached with any logistics provider (LP) at the conclusion of this research. The LP is critical in successfully implementing a milk-run operation. There are two main issues. First, the information systems and second the operational details need to be negotiated and priced. For example, as the bar-coding system generates an email to the supplier, it might also make an entry in a pick list that designates the LP's routes.

### 5.3 A SUCCESS STORY

One of the goals at the beginning of this project was to implement a pilot process that verifies the methodology and provides a working model. It was necessary to choose a difficult

situation in which there were many issues to resolve in order for this process to work. The wood supplier, which I'll call XYZ Wood, was having difficulty ensuring the product quality, causing Kodak significant downtime. I felt that this was an opportunity to get involved and not only resolve the quality problems, but also implement a test of the replenishment process.

XYZ is traditionally a store fixture manufacturer and assembles the fixtures in their facility. As problems arise, they are easy to correct within the XYZ facility. Kodak kiosk products are shipped as piece parts, not assembled units. The operations at the XYZ Wood Co. are batch processes, which lead to large quantities of finished goods inventory of Kodak parts. A Quality Manager had been hired recently to revamp their entire QA system. The quality issues discovered at Kodak were reaching unprecedented levels when I made my first trip to XYZ.

We discussed the re-occurring quality issues and discussed processes under development at the XYZ facility as a result of the escalating situation. Specifically, we discussed the implementation of a true root cause-corrective action system, standard process routings, and the introduction of SPC. I had organized a list of defects and quality issues that detailed the date, part, and specific problem encountered. The cost implications were also included. The Kodak account manager at XYZ was surprised by the detailed accounts of defects that had been encountered. I was shocked that he had not seen a similar list before. It became apparent that there was a clear lack of communication processes by which Kodak could inform XYZ of problems in a timely manner.

The measures undertaken by the quality manager would go a long way in raising the quality of Kodak parts. Several inspections were also implemented as in process checks to catch errors during the manufacturing cycle. The improvements were immediate, however there was still months of stock in finished goods that were manufactured under the previous conditions. I realized there would be a delay in the recognition of the improvements already in place at XYZ from Kodak's perspective. An interim inspection during the pick, pack and ship process would try and limit the defective parts that made it to Kodak. Eventually, after considerable attention and communication, the conditions improved. We were ready to introduce the replenishment process.

XYZ Wood Company was located in Boston, approximately 450 miles east of Kodak's Rochester facility. The company supplied 20-25 parts for the kiosk product line. These parts were large in size with pallet densities ranging from 40 to 160 parts/pallet. A production planner would call, fax, or email orders to the account representative at XYZ. The inventory levels fluctuated by part around 3-4 weeks supply and it was a common occurrence for the planner to change orders. A few occasions resulted in a call to delay a shipment followed by another call to expedite parts from the same shipment. In short, the order process was chaotic and the buyer didn't have time to pay attention to "appropriate" inventory levels.

Transportation factors were most significant in planning the replenishment logistics for these parts. The large nature and weight of the parts made shipping relatively expensive in relation to the value of the wood. We felt it was important to achieve maximum economies of scale during shipping.

Coordination efficiencies exist in the ordering process and the transportation mode. Historically, one week of demand balances out to one truckload, making coordination in this case easy. Weekly deliveries may not be sufficient after HPISM moves into the new facility, but we only required a test of the methodology. The replenishment team agreed upon the weekly review period (at least in the short term). XYZ agreed to replenish an order in two days. The resulting coverage period  $R + L$  was nine days. Using equation 2, we calculated the order-up-to points for all XYZ parts. Reviews would take place every Wednesday and orders would be delivered to the Kodak facility on Friday. Order quantities would simply replenish the amount of material used the previous coverage period.

The IT solution was not in place at this point so a manual process was developed for the test period to signal the need for delivery. After studying the MRP (Fourth-Shift) system, it was evident that, with some tweaking, we could utilize the order-up-to decision system already programmed in Fourth Shift. The system would reconcile the order-up-to level with the on hand inventory and produce a message to the buyer to purchase parts. It was the buyer's responsibility to remember to check the XYZ parts every Wednesday, a manual process that would be eliminated with the use of the bar-coding IT system. Although never used before, we successfully tested the validity of our new inventory targets and the "order-up-to" decision

process. This successful test was important on two levels. First, it tested the methodology and basic logic involved in setting the inventory targets. Second, it generates confidence in the system and allows for a broader implementation of the model.

#### 5.4 SUMMARY

As discussed in the first several pages of this thesis, technology plays a crucial role in enabling better coordination and reducing transaction costs associated with supply chain activities. Kodak decided to develop a smaller scale IT solution for this particular dilemma based on the scale and scope of this project. Perhaps at some point in the future, Kodak will migrate to a system with sophistication and complexity like Dell Computer Corporation's supply chain management system. Many of the ideas presented in this thesis are based on the early impressions and information available during the development process. Although a preliminary test of the methodology was successful, as the project continues it is expected that the ideas here will be tested and refined as necessary to ensure a robust replenishment process.

## CHAPTER 6: REFLECTIONS & RECOMMENDATIONS

### 6.1 SUMMARY

I examined a portion of Kodak's supply chain and manufacturing operations to develop an over-arching framework to think about the logistics of a new JIT/replenishment process. After considering the characteristics of the supply chain and aspects of variation, time, and cost, inventory targets are set in a manner to meet customer demand with minimal inventory. Service levels can be set in decision system models such that inventories will satisfactorily meet customer requirements without overstocking raw material. The decision system most appropriate for Kodak to use is an "order-up-to" (R, S) process. Without a sound methodology to determine inventory needs, Kodak has no basis to estimate customer service levels or evaluate performance with regard to inventory management. The replenishment based inventory control system simplified the procurement process and inventory management procedure.

### 6.2 SUPPLIER RELATIONSHIPS

Many companies have implemented innovative approaches to bring suppliers closer to the business. Honeywell's Electronic Material's division has implemented a resident supplier program to get more information directly to the supplier, faster. The resident supplier has a Honeywell badge and has access to the MRP system. Honeywell has also instituted a "win/win" supplier/customer matrix which the buyer fills in when he/she wants something from a supplier. The process forces buyers to think about the supplier perspective and work out mutual beneficial solutions. The focus of improvement shifts from price to total cost. Deere & Company has rolled out a lean supplier initiative in which supplier development is an essential part. Supplier development engineers work at supplier companies solving specific product and process problems. The supplier development program provides a means for suppliers and customers to share technology, risk, and accountability.

The supplier relationships observed at HPISM during this research were arms length. The benefits realized from my efforts to recognize the relationship and share information between



XYZ and Kodak were tremendous. Simply communicating defect data in a timely manner allowed XYZ to implement corrective actions prior to the next production lot. It resulted in approximately 65% reduction in defective parts received at Kodak. Formal processes and communication channels must be developed between HPISM and its supply base.

Furthermore, informal methods that encourage cross-organizational discovery should be encouraged. Implementing a supplier development program or other partnering initiative may help to achieve this goal. Both HPISM and its suppliers stand to gain from understanding each others operations and working together to improve total profitability.

Supplier relationships are currently managed by the commodity management organization but the daily interactions occur at a business unit level. The trade-off associated with such an organization structure is between the economies of scale achieved through aggregating the purchases across several BU's and the effect of centralizing supply decisions away from the contact points. In HPISM's case, supplier performance information and the "pain" felt by the individual BU's were both too distant from the decision-makers. The commodity management organization must become more of a service organization to the BU's, with metrics in place that include the "voice of the business unit."

Kodak can also realize significant benefits up front in the design process from closer partnerships with its supply base. The opportunity exists to outsource some of the non-core design efforts such as the kiosk cabinetry. In working with Kodak and ABC during the introduction of a next generation kiosk, I observed the frustrations on both sides. ABC's troubles stemmed from Kodak "tossing" cabinetry designs over the colloquial engineering fence. To complicate the matter further, the design was then changed numerous times, each time requiring a duplication of the approval process at (and between) both companies. In this instance, it makes sense for Kodak to outsource the kiosk design and work with the supplier regarding attribute requirements and integration with the kiosk components. The supplier has more experience and expertise working with wood and can integrate the design process with manufacturing. The resulting process enables the synergies and learning effects between design and manufacturing to develop. It also places the value producing activities where the core competence resides.

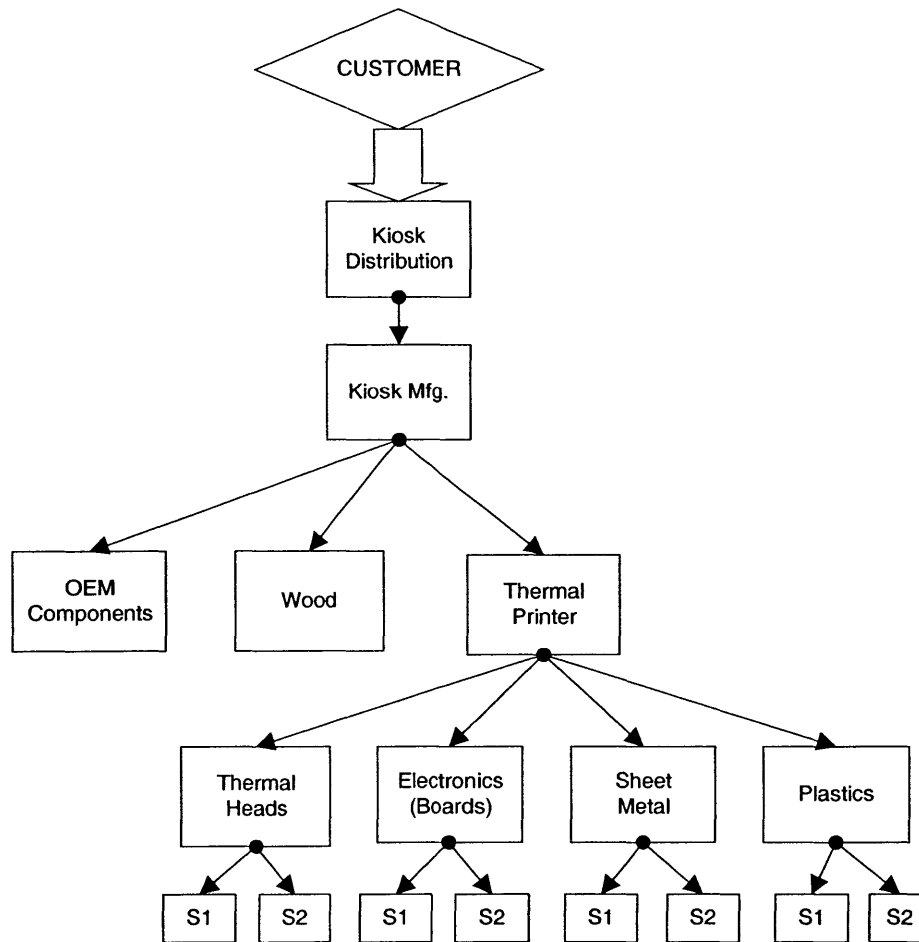
### 6.3 FURTHER RECOMMENDATIONS

I enjoyed the opportunity to work on this replenishment project but, unfortunately, due to the nature of the internship, I could not see it through to the end. Looking forward I have several recommendations that will ensure continued success for this team and the replenishment process.

The opportunity exists to extrapolate the same basic principles presented in this thesis to the global supply chain as opposed to a local functional perspective. Key decisions at this higher level includes where to hold safety and decoupling stocks to achieve the lowest total supply chain costs. The goal is to make globally optimal decisions by minimizing safety stocks and maximizing service levels at all stages. For example, kiosks are comprised primarily of OEM components, wood, and Kodak's thermal printer. A simple supply chain representation is shown in Figure 6.

Strategic inventory placement throughout the supply chain will ensure maximum customer service with minimal inventory for all supply chain partners. The identification of strategic decoupling stocks can effectively reduce the dependencies within the chain. This is particularly appealing when one part of the chain is inherently more susceptible to shortages or variation. The scope of this project necessitated a local optimization but tools like the Strategic Inventory Placement Model, developed by Graves and Willems (2000), expand the application of similar principles throughout the entire supply chain. Optimizing on a global scale will minimize cost in the entire chain while maintain a desired level of customer service at the final stage. Furthermore, it provides a sound foundation from which all supply chain partners can work. For example, one may choose to hold a strategic stock between the electronics provider and the printer assembly to serve as a decoupling stock. Circuit board availability is extremely volatile due to several components that are on allocation from sub-tier suppliers. The resulting effect on the supply chain is significant. The associated costs resulting from expediting, rescheduling or even production downtime can be avoided by effectively decoupling this part of the chain with strategic inventory.

**Figure 6. Spanning Tree Supply Chain Model – Kiosks**



Metrics and measurement are critical in evaluating success and maintaining the visibility of new programs. Metrics need to be established along with a review process to ensure the continued success of these inventory management methods. Without a formal review process, the desired change in behavior necessitated by the new model will eventually fade back to old methods and habits. The extent to which the model can be embedded into the regular systems and processes used throughout the supply chain organization should be maximized.

Web technology allows for easily scalable systems that can better integrate the supply network. The open standards and web architecture make expanding the systems easier and cheaper than

traditional EDI systems. The flexibility of TCP/IP and working via a browser with real-time information can be leverage in the spirit of this project for the benefit of the entire supply chain. Companies can automate the unnecessary person-to-person transactions by integrating systems using a universal interface (e.g. a web browser). While EDI networks provide a direct connection between Kodak and a supplier, the costs to deploy and scale such a system are extreme given the limited integration and relatively inflexible result. Furthermore, the costs may be prohibitive to some of the smaller suppliers that don't have the capital resources to invest in EDI. It would be worthwhile to further investigate browser-based technologies that enable real time collaboration throughout the supply chain. The models and decision systems described in this thesis can be integrated to automate the decision-making processes.

#### 6.4 TEAM REFLECTIONS

Overall, my team experience was very positive at Kodak. The following comments are not necessarily indicative of the project as a whole or of Kodak in the larger sense. I offer these reflections with the intent to provide some insight into the frustrations I encountered as part of this research project. My hope is to help similar endeavors that are yet to develop succeed. The following observations are based purely on the researcher's perspective and personal interpretations.

The design of the replenishment team had representation from all affected BU's, usually the supply chain manager from that area. There were only two people that were devoted to work full-time on this endeavor, the team leader and myself. There were two problems I encountered that I believe resulted in some inefficiency and hindered our ability to work as a team. First, the formal organization of the team was part-time, and separately located from one another. As the group represented four BU's, we all resided in our own BU and there was little opportunity to develop team norms and go through the team building process. We saw little of each other and focused instead on our business unit activities rather than the common goal of developing an overarching solution. As an outsider, I also found it difficult with so little interaction with the team to learn and develop the relationships I'd need at some point in the future when the project would develop momentum. It seemed each member was sub-optimizing his/her activities for their respective business unit. This activity resulted in hours of wasted activity and much frustration and/or confusion. Inherently, it seemed very difficult to

develop a standard process across four BU's, with the entire team remaining within their BU and interacting with the team only 1-2 times per week.

Job design also hindered the project significantly. As stated before, only two of us had full-time responsibility for working on this project. As such, other members were focused on other issues and could never devote a majority of their attention to a project that was not to take place for another several months. Of course, the work involved consisted of several months of effort but that is a hard sell to an organizational manager that is held responsible for fighting daily fires. The result was a very reactive rather than proactive nature and hence, very little attention was afforded for the replenishment project.

I found it particularly difficult to develop the relationships and gain the necessary knowledge from the organization. I was attempting to develop a process methodology that would apply across several BU's, while I was reporting to a specific BU supply chain manager. In other words, I don't feel I was working at an appropriate level in the organization to effectively influence the decision makers. It was difficult to develop the trust I needed because I "belonged" to a particular BU and therefore may have been viewed as biased.

Another interaction between the organizational structure and the effectiveness of the team stemmed from our relationship with commodity management. The process under development had to be rolled out, presented and negotiated with suppliers for it to work. The clarity as to who was responsible for accomplishing that task was vague at best. Commodity management "owned" the relationship and was ultimately responsible for negotiations, but was relatively uninvolved primarily because of a lack of understanding as to the implications of the new process. Commodity managers wound up setting supplier meetings up, while our team met and opened negotiations regarding our replenishment needs. Even as my internship drew to a close, this relationship seemed undefined and varied depending on the particular commodity manager involved.

In order for this team to execute successfully during the implementation phase of the project, I believe some changes to the organizational structure would help. First, the team needs to be co-located with additional full-time members to facilitate communication. Second, roles and relationships need to be defined between the commodity management group and the

replenishment effort. Suppliers will be evaluated (by commodity management) as to their ability to deliver product within the constraints of this new system, and commodity management needs a better understanding of the process. From an LFM student's perspective, it would work better if reporting to the site supply chain manager and project champion. Such a change would locate the LFM closer to the daily activity and allow more of an opportunity to develop appropriate relationships, build credibility and better influence decision makers.

## BIBLIOGRAPHY

- Black, B. E. June 1988. "Utilizing the Principles and Implications of the Base Stock Model to Improve Supply Chain Performance." S.M. Thesis, Leaders for Manufacturing Program, MIT, Cambridge, MA.
- Caldwell, Bruce and Bob Violino, "Hyper-efficient Companies" Information Week, Manhasset, Mar 1, 1999, pp. 40-48
- Graves, Stephen C. and Sean P. Willems "Optimizing Strategic Safety Stock Placement in Supply Chains" Manufacturing and Service Operations Management, Vol. 2, No. 1, Winter 2000, pp. 68-83
- Joachim, David, "Dell Links Virtual Supply Chain" Information Week, Manhasset; Nov 2, 1998, pp. 1-3
- Morrison, Christopher A., May 2000. "Product Development Process Assessment." S.M. Thesis, Leaders for Manufacturing Program, MIT, Cambridge, MA.
- Nahmias, S. Production and Operations Analysis, Burr Ridge, IL: Richard D. Irwin, Inc., 1993
- Sheridan, John H., "Now it's a Job for the CEO" Industry Week, Cleveland; Mar 20, 2000, Vol. 249, Iss. 6; pp. 22-29
- Silver, Edward A. and Peterson, Rein Decision Systems For Inventory Management and Production Planning, New York: John Wiley & Sons, Inc., 1985
- Verespej, Michael, A., "Michael Dell's Magic" Industry Week, Cleveland: Nov 16, 1998