LEAN SUPPLIER RELATIONSHIPS IN THE UNITED KINGDOM

by

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Submitted to the Sloan School of Management and the Department of Chemical Engineering in Partial Fulfillment of the Requirements for the Degrees of

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ABSTRACT
The Eastman Kodak Company’s Annesley, United Kingdom facility assembles consumer and professional film for distribution to the European, Middle Eastern, African, and Russian (EAME) region. Under pressure from digital photography, Kodak is managing the traditional film business for cash to fuel strategic initiatives throughout Kodak. Thus, cost reduction is a focus of the Annesley facility.

This thesis describes a cost reduction initiative in the Annesley facility’s component supply chain to eliminate a storage and staging warehouse. The specific tools used to complete this effort include the use of Strategic Inventory Placement (SIP) modeling\(^1\), implementation of kanbans, and application of excess inventory calculations. The intent of applying the SIP model was to find unnecessary inventories. Instead, the model revealed key supply chain challenges and constraints for the project to overcome. Kanbans were implemented across the Annesley and vendor sites\(^2\). The design of these kanbans provides incentives to drive further lean improvements at Annesley and the vendors. Kanban sizes were calculated by a maximum per lead time methodology. This methodology provides a better estimate of demand variability than the reorder point, order up to methodology previously employed. Finally, the optimal stock level was calculated for components with excess inventories\(^3,4\). The results of these calculations were combined with knowledge of future demand to reduce inventory to optimal levels.

Through completion of this work the component storage and staging warehouse was closed. The kanban systems improved customer service while lowering inventories through improvement in inventory record accuracy. Using the optimal inventory calculation, excess and obsolete inventories were eliminated. These actions allowed sufficient inventory to maintain Annesley’s production to be located at the Annesley site.

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1: INTRODUCTION

1.1: KODAK BACKGROUND AND PROBLEM STATEMENT

The Eastman Kodak Company is a world leader in imaging technologies. Kodak’s ascent to this position is due in large part to the success of their photography segment, which supplies film, paper, and other photography related products and services to the consumer, entertainment, and professional markets. Recently Kodak experienced a decline in this segment, led by a decline in film sales. The decline in sales prompted Kodak’s leadership to pursue a strategy of maintaining traditional photography as a revenue generator to fund investments for the future. A press release on Kodak.com detailed this strategy, “In the short term – the next 2 years – the company will reinforce its foundation by cutting costs and by managing the consumer film and paper businesses for cash and manufacturing share.”

One area of potential cost savings recognized by Kodak was the component supply to the Annesley, UK film finishing facility. More specifically, Kodak felt that elimination of a staging warehouse for incoming materials (referred to as the hub) would yield significant cost savings. This thesis focuses on Annesley’s component supply chain and the measures taken to eliminate the hub. These measures included Strategic Inventory Placement (SIP) modeling, transition from reorder point inventory management to kanbans, and disposal of excess inventory. Following the discussion of hub exit, recommendations for further improvements to Annesley’s component supply chain are proposed.

1.2: ANNESLEY BACKGROUND

Kodak’s Annesley site is located approximately 10 miles north of Nottingham in the Midlands region of the United Kingdom. The Annesley site spools and finishes 35 mm, 120 mm, and APS film for the European, African, Middle Eastern, and Russian

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(EAMER) region (further discussion of the EAMER region is in section 1.3). Annesley’s production schedule is highly seasonal with the peak of sales occurring over the summer months. To cope with this seasonality, the facility utilizes a large number of temporary and contract employees.

1.2.1: The Film Finishing Process

Figure 1.1 illustrates the film finishing process used at Annesley. The black boxes represent steps of the process that occur at the Annesley facility. The remaining boxes represent critical, external inputs to the film finishing process. The immediate sources of the external inputs to the process are noted in parenthesis.

Figure 1.1: Film Finishing Process at Annesley

The major processing steps at the Annesley facility are Metals, Spooling, and Packaging. The process begins with the creation of a magazine to house the film in the Metals area (see Figure 1.2 for a typical film assembly). The magazine is formed by stamping lithographed sheet steel into a metal cylinder. Velvet is affixed to the magazine to provide a light proof opening for the film to pass through. Roll steel is stamped into end caps that are inserted into one open end of the magazine.
The spooling area winds film around a plastic spool and places it in a magazine. This is followed by insertion of an end cap into the remaining open end of the magazine. With insertion of the end cap the film magazine is complete. The final step taken in the spooling area is to insert the completed magazine into a plastic can and then cap the can with a plastic lid.

The final major step in the Annesley finishing operation is packaging. The film is first packaged into a carton. Depending on the specifics of the order, the film may be placed into a secondary packaging (such as a plastic bag or overcarton). Finally, the cartoned film is placed into cases, palletized, and shipped either to the Pack Centre or to a distribution centre.

1.2.2: Manufacturing Initiatives at Annesley

There are two major manufacturing initiatives at the Annesley facility relevant to the hub exit project. The first of these is Kodak’s strategy to mirror the Toyota Production System in an attempt to become lean. The Kodak Operating System (KOS) Office, created specifically for the dissemination of lean principles throughout Kodak, spearheads this initiative. The hub exit project must align with the Annesley facility’s lean vision for the project to be considered successful.
The second major initiative involved outsourcing of the plastics operation. This outsourcing occurred during the planning stages of the hub exit project. As a result, floor space for storage of components became available at the Annesley facility.

1.3: EAMER BACKGROUND

To provide high quality service to the global marketplace, the Eastman Kodak Company has divided the world into several regions. This allows Kodak to provide products best suited to each region. The Annesley facility is located within the EAMER region.

1.3.1: Supply Chain

The Annesley facility provides finished film for consumer and professional imaging division of the EAMER region (Figure 1.3 shows the EAMER film supply chain).

Figure 1.3: EAMER Supply Chain

The film finishing process revolves around the film, which is the highest value component. Kodak facilities located in Chalon, France and Rochester, USA provide sensitized film to Annesley. The Annesley facility winds and packages individual rolls of film for distribution. Raw materials other than film, such as packaging components, are
supplied either through a warehouse (known as the hub) run by a third party logistics provider or directly from the vendor. Finished film that will be sold as part of a promotion is sent to the Pack Centre where it prepared for the promotion (i.e. packed into floor standing merchandisers). Kodak distributes its film to customers (primarily wholesalers and retailers) through a two-tiered distribution chain of central distribution centres (CDCs) and regional distribution centres (RDCs).

As part of the lean vision for the EAMER supply chain developed by the KOS office, the DCs hold inventory of all finished items. This allows inventory at the DCs to absorb variation in customer demand. Kodak utilizes the buffering effect of the DC’s to smooth demand signals sent to the Annesley facility.

1.3.2: Product Modifications and Proliferation

The EAMER sales and marketing organizations are divided into clusters. Each cluster represents a specific country or group of countries. This organizational structure allows Kodak to tailor its product offerings and promotions to specific cultures. There is intense pressure on the clusters maintain or grow market share. To achieve market share goals the clusters frequently develop new products and modify existing products. Introduction of new products by each of the clusters creates a large portfolio of end items that Annesley must produce. Frequent modification of end items requires significant resources be dedicated to managing component inventories and end items through product launch and discontinuation.

Product proliferation in Kodak’s portfolio begins with the different sensitized films (i.e. Gold or Ultra film) provided by the Rochester and Chalon facilities. Further differentiation is created in spooling as film is cut to different exposure lengths (12, 24, and 36) and placed in magazines carrying different languages. Given that multiple languages are often printed on the magazine, the number of spooled products is only about six times the number of sensitized film types. In the packaging area, the number of products explodes due to regional requirements for cartons that vary by language, format (i.e. hang tab boxes and PVC blister packages), as case and bundle quantities. The number of finished items is approximately 20 times the number of sensitized film types.
Kodak maintains market share and a powerful brand image through promotions and by frequently updating packaging graphics. As a result of this strategy, the typical lifetime for a given graphic design is about one year. Unfortunately, the recurrent packaging changes lead to difficulty in managing inventory levels. Inventory levels are often set based on the often incorrect assumption that an updated design will follow a similar demand pattern to its predecessor.

1.4: Annesley Component Suppliers

A diverse set of companies with a wide range of constraints supply components to the film finishing process. Among the suppliers, several are considered highly important to the supply chain because their constraints do not match favorably with Kodak’s requirements. The two constraints that generally present the greatest issue for suppliers are lead time and lot size.

The Annesley facility has a promised lead time for typical deliveries to the DC’s. Many of Annesley’s suppliers have lead times in excess of this typical delivery time. The mismatch in lead times requires Annesley’s suppliers to hold component inventories. This does not create much difficulty for suppliers of generic items, such as plastic spools, used in a large number of Annesley’s products. Since the generic items are used in nearly all of Annesley’s products, they have a relatively low coefficient of variation and therefore a small safety stock. However, for highly differentiated items, such as packaging material, the mismatch in lead time is extremely costly. These items have high coefficients of variability and consequently large safety stocks. As a result, the highly differentiated items have higher inventory costs and challenge Annesley’s and supplier’s space constraints.

In addition to lead time issues, many of Kodak’s suppliers also struggle with lot sizing. In keeping with the lean vision, Kodak wants to run fairly small lots. The small lot sizes create issues with suppliers trying to gain economies of scale by running larger orders. As with lead time, the lot sizing issue causes the component supply chain to maintain inventory. The inventory cost and space constraint issues generated by the inventory are more significant for highly differentiated products than for generic products.

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Kodak continually pressures suppliers to continue to shorten lead time and lot sizing. The pressure on suppliers is largely attributed to Kodak’s drive to become lean and achieve single piece flow. Unfortunately, many of the suppliers feel that their production costs are increasing with the decreasing lot sizes Kodak requests. In most cases the perception that smaller lots are costing suppliers money is an artifact of the accounting systems. However, the perception does exist and generates resistance to requests for decreased lot sizes.

1.5: The Hub

The initial vision of the hub was of a warehouse near the Annesley facility that would be a staging area for all of the components needed for the film finishing process. Kodak and their suppliers would share the financial responsibility of the hub, based on storage space required and value of the product being stored. This space would provide components to Annesley on a short lead time (several times a day). The hub also provided storage space that addressed the issues of product proliferation, sales variability, component lead time, and component minimum order quantities (MOQ).

Over time the amount of space used at the hub gradually increased until it peaked at over 5,000 pallet spaces. The pallets were stored in six different units consisting of three aisles each (Figure 1.4 shows a typical aisle at the hub). Proliferation of products, desire to improve customer service, and the human tendency to fill the space available primarily drove the increase in required storage space.

As the hub grew so did its cost. However, the contribution of the suppliers storing materials in the hub did not increase. Consequently, Kodak shouldered the elevated financial burden. Additionally, with the increase in stock at the hub, inventory record inaccuracies became commonplace. All of this led Kodak management to state that Kodak was going to “Get out of the hub.” Implicit in this statement was that cost for component supply would not increase and that service levels would be maintained.
Figure 1.4: Inventory at the Hub
2: STRATEGIC INVENTORY PLACEMENT MODELING

Before attempting to eliminate the hub, Annesley's component supply chain was analyzed to determine which, if any, of Annesley's component supply inventories were unnecessary. This analysis was a necessary first step to determine if there were any easy wins through inventory elimination. Additionally, this analysis would provide guidance on how to proceed with the hub exit while maintaining Annesley's service rate. This analysis was executed through creation of a Strategic Inventory Placement (SIP) model.

2.1: SIP MODEL OVERVIEW

The SIP model provides a methodology to determine the optimal holding points for inventory through a supply chain. The following paragraphs will provide a cursory explanation of how a supply chain is optimized using SIP modeling. Further detail regarding SIP modeling can be found in work completed by Graves and Willems\textsuperscript{10,11,12}.

The first step in constructing the model is to determine the topology of the supply chain in question (serial line, assembly network, distribution network, or general network). Then the supply chain steps, or nodes, are numbered from 1 to N, where N is the total number of steps in the network. The numbering procedure is dependant on the network topology.

The cost of holding inventory at a given node is determined by calculating the necessary safety stock for the node by the equation (descriptions of symbols are located Appendix A):

\[ SS_i = h_i \cdot k_i \cdot \sigma_i \cdot \sqrt{LT_i} \]  \hspace{1cm} (Equation 2.1)

The replenishment lead time \((LT_i)\) in the base inventory model can be rewritten for each step in terms of the promised lead time of the preceding step \((S_{i-1})\), the production time of the step \((T_i)\), and the promised lead time of the step \((S_i)\). For steps with more than one predecessor, the longest promised lead time is used.


\[ SS_i = h_i \cdot k_i \cdot \sigma_i \cdot \sqrt{S_{i-1} + T_i - S_i} \quad (Equation \ 2.2) \]

Using this formulation, the promised lead time of each of the steps can be varied to minimize the safety stock cost of the node.

Constraints must be applied for the model to find the appropriate solution. First, the promised lead time of a step cannot be less than zero or greater than the sum of the production time of that step plus the promised lead time of the precursor step. Mathematically, this constraint can be represented as:

\[ 0 \leq S_i \leq S_{i-1} + T_i. \quad (Equation \ 2.3) \]

If \( S_i \) is strictly less than \( S_{i-1} + T_i \) then inventory must be carried in the supply network. The model must be constrained such that the lead time of the supply chain is acceptable. This can be accomplished by constraining the service time of the final stage in the network (\( S_N \)) to be less than or equal to the desired overall lead time.

The model determines the optimal inventory placement via a forward recursive algorithm. This algorithm finds and retains the service time of the upstream node or nodes that minimize the cost of each successive node. This procedure continues through the end of the network. The solution found at the final node is the optimal solution for the entire network.

The total number of potential solutions for a network is equal to the product of the number of possible lead times for each step. For instance, a serial network consisting of three nodes that each have possible service times between 0 and 10 has a \( 11^3 \) or 1331 solutions. For the Annesley network, the number of possible solutions is well into the billions. However, by employing the forward recursive methodology, the algorithm only considers the optimal solutions from previous steps. For a serial network of three nodes and service times of 0 through 10 the number of possible solutions is reduced to 242. For the Annesley network, the number of potential solutions falls below 10,000.

The "all or nothing" pattern\(^{13} \) (each node either has no inventory or enough inventory to decouple the node from downstream steps) increases the computational efficiency of the model further. The algorithm only needs to investigate service times that represent zero inventory at the node or sufficient inventory to decouple the node.

\[^{13}\text{Simpson, Kenneth F. "In-process Inventories." Operations Research 6.6 (1958): 863-873.}\]
from downstream processes. In the case of the Annesley network, this eliminates nearly 75% of the remaining possible solutions.

The SIP model makes several assumptions. The first of these assumptions is that lead time is deterministic and not capacity constrained. For example, an order for 1,000,000 sales units will have the same replenishment lead time as an order for one sales unit. The second assumption of the model is that demand is normally distributed. This assumption manifests itself in the safety stock calculation used in the model, which is based on a normal distribution. Finally, since the model uses historical data there is an implicit assumption that past demand will be representative of future events.

2.2: Application of the Model

Prior to construction of the SIP model, the appropriateness of the model in light of its assumptions was considered. The first assumption, that the supply chain is not capacity constrained does not represent a major problem. As a general rule, the Annesley facility is able to flex labor to meet sales requirements. The assumption that demand is normally distributed is not applicable on an item-by-item basis (for example, a promotional item would be expected to have a different demand pattern). However, when the demand for all of the items is pooled a normal demand distribution is created (via the central limit theorem). The final assumption is that past demand will be representative of future demand. This assumption is met as overall film sales in the EAMER region are fairly stable.

The SIP model of the Annesley facility was constructed using the Visual Basic Macro capability of Microsoft Excel. In addition to the major steps of the Annesley facility, the major steps of carton production were included. These were included because management of cartons has proven to be one of the major difficulties of the supply chain.

The first step in constructing the model was to determine the topology of the network. In the case of the Annesley facility the topology is that of a simple assembly network (see Figure 2.1).

One of the inputs required for the SIP model is the total acceptable lead time for the supply chain. The Annesley facility has a standard lead time to its customers (Kodak
DC’s). However, if a DC stocks out of an item, the lead time required from Annesley can be significantly less than the standard lead time. For this reason the supply chain was modeled for the standard lead time, a moderately expedited lead time, and a highly expedited lead time. The results of the model runs are in Figures 2.2, 2.3, and 2.4.

Figure 2.1: SIP Model of Annesley and Carton Supplier Processes

An expected result of the model is that as lead time becomes shorter, the cost of the inventory holding increases. For the standard lead time the calculated inventory required is $100 (adjusted) with approximately 13 inventory turns per year. In contrast the moderately expedited and highly expedited lead times have costs of $145 (10 inventory turns) and $258 (nine inventory turns), respectively. By comparison, Annesley was actually achieving about four inventory turns per year.

The triangles in Figure 2.2 show which steps the SIP model decouples from downstream processing by an inventory buffer for the standard lead time case. The SIP model recommends inventory of all of the long lead time inputs (board, ink, roll steel,
sheet steel, velvet, and film). Additionally, the model suggests that inventory be kept at the carton cut step. This inventory hold point is required because the replenishment lead time for cartons is greater than Annesley's standard lead time.

Figure 2.2: SIP Model Results for Standard Lead Time

![Diagram showing flow of inventory from Board, Ink, Roll Steel, Sheet Steel, Velvet to Carton Print, Carton Cut, Carton Glue, Metals, Spooling, Packaging, and finally to Ship to DC or Pack Centre with a cost of $100.]

To meet the constraints of the moderately expedited lead time (Figure 2.3) several changes in inventory positioning occur. The inventory held after carton cut for the agreed lead time case moves to carton glue to improve the replenishment time of cartons. Inventory hold points are added at the metals, plastics and cases steps. In the moderately expedited process the spooling operation still functions on a make to order basis.
Figure 2.3: SIP Model Results for Moderately Expedited Lead Time

Figure 2.4: SIP Model Results for Highly Expedited Lead Time

Addition of inventory after the spooling step is the most significant change in inventory positioning found for the highly expedited lead time. This move in inventory
represents a major increase in inventory value because spooling is the highest value added operation in the Annesley facility.

In practice inventory exists at nearly all of the processing steps of the Annesley facility. However, the Annesley facility is not managed with the “all or nothing” inventory policy that the SIP model recommends. Instead, smaller quantities of inventory (insufficient to decouple a step from downstream processing) are held at nodes that require inventory to respond to a highly expedited response. This allows the Annesley facility to provide the responsiveness required by their customers, but only for a short period of time.

2.3: SIP Model Conclusions

Creation of a SIP model is achievable through application of the Graves and Willems methodology and the Visual Basic capabilities of Microsoft Excel. Development of the model highlighted a couple of key challenges to be addressed in elimination of the hub. First, for the immediate future no single component inventory can be completely eliminated. Instead, each of the components for which inventory currently exists in the hub must be managed either at the Annesley facility or by the vendor. Additionally, the model results highlighted the need of the supply chain to maintain the responsiveness required for expedited situations in order to maintain Annesley service level. Beyond the Annesley site, the SIP model illustrated a need to investigate the root cause of expedited orders. The model demonstrates that a single lead time expectation for the Annesley facility results in significant savings and double inventory turns. Chapter 5 contains further discussion of this topic.
3: INVENTORY MODELS – REORDER POINT VS. KANBAN

Kodak management recognized that to move out of the hub without increasing cost or damaging service levels the materials management policies of the Annesley facility needed modification. This chapter discusses the traditional method of materials management and the transition to materials management guided by the principles of the Toyota Production System.

3.1 REORDER POINT ORDER UP TO OVERVIEW

Material management at Kodak’s Annesley site was historically achieved by setting inventory levels through the use of reorder points (ROP) based on historical data. The typical ROP used at Annesley was set via the following equation:

\[ ROP = DDLT + z \cdot \sigma \cdot \sqrt{LT} \]  

(Equation 3.1)

To manage inventory by using this method, the inventory quantity is allowed to decrease until it is less than or equal to the ROP. An order for additional material is placed once the ROP is reached. The size of the order is equal to the order up to level (calculated as a percentage of ROP) minus the inventory in stock. If the order quantity is less than the minimum order quantity (MOQ) then the MOQ is purchased. The remaining inventory maintains production until replenishment occurs.

For the ROP system to be used several conditions must exist. Calculation of the ROP requires that the distribution of the demand is normal. Additionally, for the ROP to be effective historical demand must be representative of future demand. Finally, demand events need to be uncorrelated.

3.2 APPLICATION OF THE ROP ORDER UP MODEL

The issues that Annesley faced in maintaining inventory levels through the ROP model can be illustrated by reviewing the model assumptions and execution of the model at Annesley.

3.2.1: Normally Distributed Demand

Calculation of a ROP requires normally distributed demand. Unfortunately, the sales of individual sales units (a specific exposure and grade of film packaged in a
specific carton) in the EAMER region are seldom normally distributed. Through the central limit theorem, demand for generic items (such as plastic spools) is normally distributed. Two examples illustrate the issue that non-normal demand causes. The first of these examples, shown in Figure 3.1, illustrates typical, sporadic demand for a carton. Figure 3.2 contains demand data for one of the consistently demanded cartons. The independent axes in both Figures 3.1 and 3.2 are the actual value divided by the average daily demand of the carton.

Figure 3.1: Sporadic Carton Demand Data

![Figure 3.1: Sporadic Carton Demand Data](image)

Figure 3.1 demonstrates the difficulty that sporadic demand patterns present to the ROP model. In this figure the inventory level falls to zero and a stock out occurs. This occurs despite the fact that the average inventory level in Figure 3.1 is approximately 26 times the average daily demand. Comparatively, the consistent demand in Figure 3.2 requires an average inventory level of approximately 11 times the average daily demand and does not result in a stock out.

The data in this example is recorded on a daily basis. Any day in which Kodak generated no sales a value of zero is logged. By constructing the data in this manner, each day is an individual event. With this formulation, a ROP model would achieve its required service level primarily through providing “service” on the days in which there is
no demand. If the ROP is recalculated for the data in Figure 3.1 with the zero sales days excluded, the consequent ROP is increased by approximately 2.5 times. This increased ROP would eliminate the stock out, but would also increase the average inventory level to over 60 times daily demand.

Figure 3.2: Consistent Carton Demand Data

Unfortunately, the sales pattern of the majority of end items produced at the Annesley facility are more similar to the sporadic data of Figure 3.1 than the data of Figure 3.2. Therefore, management of components specific to an end item (such as cartons) cannot be successfully accomplished through application of the ROP model. However, many of the components (such as plastic spools) are fairly generic and used in a wide range of end items. By the central limit theorem, the demand distribution for these items is normal. In practice, the normality of the data represents itself in the relative success that Kodak has had managing these items.

3.2.2: Historical Stability of Demand

The ROP model, like all models based on historical data, assumes that sales are historically stable. Stated another way, the ROP model assumes that past trends are good predictors of future events. However, with over 100 promotions of nearly as many end
items every year and a portfolio that turns over about once a year, this assumption does not hold for the Annesley site. Since the majority of product modifications involve only the product packaging, this assumption presents an issue only for end item specific components. The total sales rate of items produced at the Annesley facility are fairly consistent and predictable from year to year. Therefore, demand for generic components is relatively stable.

3.2.3: Uncorrelated Demand Events

A final assumption of the ROP model is that sales are uncorrelated events. However, Kodak sales are often correlated. A significant number of promotions focus on a specific time of year or event (i.e. Christmas or the 2004 Summer Olympics). The result of the timed nature of promotions is that the end item will sell at a very high rate for a short period of time. A period of low or zero sales generally follows this high sales rate period. As a result the ROP will typically be set too low on specific components to achieve the desired service level. Conversely, if ROPs increase to account for correlated demand excess inventory of many components would be purchased.

3.2.4: Execution of the ROP Order Up To Model

While the differences between the assumptions of the ROP model and the reality of the Annesley supply chain are significant, greater difficulty stems from execution of the model. Inventory accuracy issues and human intervention in the model, such as forecasted buying, cause the largest sources of execution problems. These problems are discussed in the following paragraphs.

For an ROP model to function well, the inventory data used to determine when to replenish a component must be accurate. Unfortunately, the configuration of the Annesley component supply chain makes inventory accuracy problems likely. The aspect of this configuration that causes the issue primarily relates to the location of the inventory and the inventory records (Figure 3.3). Note that the inventory accuracy issue is related to the supply chain configuration, and is not caused by use of an ROP system.

The component supply chain for Annesley can be segregated into three physical locations, the vendor site, the hub, and the Annesley site. Inventory and inventory
management systems exist at each of these physical locations. A Kodak employee located at the Annesley site (represented in Figure 3.3 as the Decision Maker) is responsible for maintaining the appropriate inventory levels in the supply chain. In order for the Decision Maker to determine if additional components are required in the component supply chain he must determine the total quantity of the Vendor and Kodak-owned stock in the chain. Vendor-owned inventory was maintained at two different locations and managed through the vendor’s and the third party logistics provider’s inventory management systems. Kodak-owned inventory was located at the hub and at Annesley and managed by the third party logistics provider’s and Kodak’s inventory management systems. The highly segregated nature of inventory and data required a large amount of communication between the sites. With the necessity of this communication comes the need for a significant amount of labor and ample opportunity for errors.

Figure 3.3: Inventory and Inventory Record Flows
Perhaps more significant than the communication issues was the location of Kodak-owned stock at the hub. Kodak-owned inventory frequently moved from the hub to Annesley and back. Inventory sent to the hub from Annesley usually consisted of excess components remaining at the completion of a production run. Errors in the inventory transactions of Kodak-owned stock between Annesley and the hub often went unnoticed. This was because the third party logistics supplier was not responsible for management of the Kodak inventory at the hub. Consequently, they did not perform physical verification of inventory levels (this activity was performed for the Vendor owned stock that the logistics supplier at the hub). Additionally, since the inventory was located outside of Annesley, physical verification by Kodak employees occurred infrequently.

The physical segregation of component inventories and the complexity of the information flows led to frequent inventory record errors. An inventory record is accurate if the physical quantity of an item in stock was within five percent of the inventory record. A physical count of the Kodak-owned inventory at the hub revealed that only about 70% of inventory records were accurate.

This degree of inaccuracy has two major impacts on the materials management at Annesley. If the inventory record states that there is more inventory than actually exists, there is an elevate risk of stockouts. If the inventory record states that there is less inventory than actually exists, Kodak experiences a greater level of obsolescence.

The issue of overstated inventory can be demonstrated by analyzing the impact this error would have on service levels of an item. From the ROP equation:

\[ ROP_{\text{ Desired}} = DDLT + z_{\text{ Desired}} \cdot \sigma \cdot \sqrt{LT} \]  
\[ (Equation 3.2) \]

An overstatement in the inventory record will result in the effective ROP of the system to be decreased, in terms of the fraction of the desired ROP, by the amount of the overstatement \( (E) \):

\[ ROP_{\text{ Effective}} = (1 - E) \cdot ROP_{\text{ Desired}} \]  
\[ (Equation 3.3) \]

The safety factor for the effective ROP can be expressed as a function of the overstatement:

\[ z_{\text{ Effective}} = (1 - E) \cdot z_{\text{ Desired}} - E \cdot \frac{DDLT}{\sigma \cdot \sqrt{LT}} \]  
\[ (Equation 3.4) \]
Figures 3.4 and 3.5 show the impact of inventory overstatement on the demand data used in Figures 3.1 and 3.2.

Figure 3.4: Impact of Inventory Overstatement on Service Level of Sporadic Demand Data

Figure 3.5: Impact of Inventory Overstatement on Service Level of Consistent Demand Data
In both the case of sporadic and consistent demand, inventory overstatement has a profound impact on the effective service level. The impact is particularly large in the consistent demand case. This is due to the relatively small safety stock that is required for consistent demand.

Understatement of inventory directly increases the Kodak’s obsolescence costs. In the case of understated inventory the decision maker will perceive a need for additional material before it actually exists. This results directly in over ordering costs. Since a stock out of material is less likely in this case, correction of the inventory error is improbable. With the quick portfolio turnover Annesley experiences, the over ordered inventory will likely be scrapped.

In addition to inventory accuracy, difficulty is also encountered in applying the rules of the ROP model. For instance, if a large order is expected to occur for a given item, those responsible for maintaining component inventories will often order material before the inventory level drops below the ROP. This behavior is understandable in the face of poor inventory data and the pressure to not run out of components. However, errors in accurately forecasting which items are needed results in unnecessary inventories.

The problem of forecasting error is largest for promotional items. Components for promotional items are ordered based on a forecast prior to launch of the promotion. Any overstatement of demand in the forecast results in overstocking of components.

3.3 Kanban Overview

Kanban, which is defined as “tag-like card that communicates product information”, is a tool used in a kanban system to achieve just in time (JIT) production\textsuperscript{14}. Another way to define kanban is as follows:

“\textquote{We define kanban scheduling as demand scheduling. In processes controlled by kanbans, the operators produce products based on actual usage rather than forecasted usage ... The kanban schedule replaces the traditional weekly or daily production schedule most of us have become familiar with in manufacturing operations. This schedule is replaced with visual signals and predetermined decision rules that allow production operators to schedule the line.}\textsuperscript{15}"

\textsuperscript{14} Monden, Yasuhiro. \textit{Toyota Production System: An Integrated Approach to Just-In-Time}. Engineering & Management Press, 1998

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There are multiple advantages of kanban control systems over other inventory control methods. The most pertinent of these advantages to the Annesley site include reducing inventory, preventing overproduction, placing control with production operators, improving responsiveness to demand change, and minimizing obsolescence. Many of these advantages stem from simplifying and eliminating flows.

3.4 APPLICATION OF KANBANS

Kodak recognized that to get out of the hub the inventory management system would need modification. From analyzing Figure 3.3, two forms of waste are apparent. These wastes are transportation of goods without any purpose and unnecessary processing steps\textsuperscript{16}. Based on experiences at other sites throughout Kodak (including the Pack Centre) and the Kodak’s strategic direction towards lean, a decision was made to convert to kanban systems. This transition was expected to improve the inventory management execution.

Design of a kanban requires consideration of the kanban structure, operation, and size. Each of these aspects of the kanban design is discussed in the following sections. Then an example kanban system will demonstrate the details of the Kanban design and operation used at the Annesley facility.

3.4.1: Kanban Structure and Sizing

To create working kanbans while ensuring that the kanbans reinforced the appropriate behaviors in Kodak’s suppliers, the kanban structure shown in Figure 3.6 was created.

Orders entering the Annesley facility for production are generally unpredictable in both timing and size. Additionally, these orders are not normally distributed. A method of sizing the kanban that accounted for demand variability was needed.

The solution to this issue was found in the production limitations of the Annesley facility. Regardless of demand, there is a finite amount of each item that will be produced on a single day. To take advantage of this fact, the amount of inventory in the

The actual quantity of material held in the Vendor and Kodak kanbans was calculated by the following procedure. First, the maximum component usage over the replenishment lead time was used to size the total number of kanban spaces (rounded up to the next whole kanban space) in the supply chain. Second, the maximum usage over the delivery period (rounded up) for a given item was used to size a kanban at Annesley. One additional space was generally added to the Annesley kanban to provide a buffer against delivery issues, such as traffic delays. The supplier maintains a kanban inventory equal to the inventory needed in the supply chain minus the kanban quantity held at the Annesley facility.

With this configuration the number of information flows required to signal the vendor to start production drops from seven (Figure 3.3) to three (Figure 3.6). The drop in required information flows is due to simplification of the chain by elimination of the hub and use of visual controls of inventory level in lieu of computerized inventory
management systems. Not only does this reduce the likelihood of inventory accuracy issues, but also eliminates the role of the decision maker.

The kanban configuration of Figure 3.4 incentivizes several desirable behaviors throughout the component supply chain. First, since the variability in Annesley’s production determines the total amount of inventory in the supply chain, Kodak has an incentive to improve their ability to level production. Also, with the kanban placed under the control of the factory floor the operations personnel are able to witness the impacts of their decision on material flow firsthand. As leveling improves, the kanban sizes can be reevaluated and reduced. Second, the kanban configuration provides the vendor with a large incentive to drive down their lead time. Because the inventory held at Annesley is dependent only on the delivery lead time the vendor receives all of the inventory reduction benefit of any replenishment lead time improvements. For an inventory management system to truly be a kanban system, the replenishment lot size must equal the withdrawal lot size. This is not true for a number of vendors. For these vendors production occurs only when the inventory falls to the point that a signal is sent by the kanban. Since one empty kanban space triggers a production order at the vendor, the vendors minimum order quantity impacts the average inventory in the component supply chain. Again, since Annesley only holds inventory to cover the delivery lead time, any reductions in minimum order quantity will result in reduced inventory costs to the supplier.

3.4.2 Kanban Operation

Operation of the Kanban system begins when the Annesley facility needs material for production. The inventory is moved to the production line where it is to be consumed. Depending on the signaling scheme developed for the specific component, a Kanban card may be removed from the component placed in a Kanban post (if this is not done, then removal of the material is the information signal). At a set time the signals are gathered (either by counting Kanban cards or by counting empty inventory spaces) and transmitted to the vendor. The vendor responds by removing the requested inventory from their Kanban for delivery to Annesley at a specified time (generally the following day). Removal of the material from the vendors Kanban then triggers production by the vendor.
3.4.3: Hypothetical Kanban Design and Operation

To demonstrate the design and operational details of this inventory control system, two hypothetical kanbans were created based on the demand data used in Figures 3.1 and 3.2. The hypothetical components have the following characteristics. Each component is produced and shipped in whole pallet quantities. The minimum order quantity from the vendor is 2.0 pallets. Annesley’s maximum usage, regardless of demand, is 2.0 pallets per day for both components. The replenishment lead time of the components is seven days and component delivery to Annesley occurs on a daily basis (based on an order from Annesley on the previous day) immediately prior to counting of the Kanban cards or empty inventory spaces.

The maximum demand of the sporadically demanded component over seven days is equal to 4.01 pallets, and the maximum demand over one day is equal to 3.39 pallets. The maximum demand of the consistently demand component over seven days is 3.62 pallets, and the maximum demand over one day is 1.95 pallets.

The first step in designing the Kanban system is to determine the total amount of component inventory to maintain in the system. Since the component can only be produced and shipped in full pallet quantities, the total number of pallets in the system to cover maximum usage over the lead time is five for the sporadically demanded component and four for the consistently demanded component. Next, the size of the Annesley kanban must be determined. Based on historical data the size of the kanbans at Annesley should be four pallets of the sporadically used component and two pallets of the consistently used component to cover one day's use. However, the maximum quantity of these components that Annesley can consume is two pallets per day. An extra pallet is added to the Kodak kanban to account for delivery issues (such as heavy traffic). Therefore, the Kodak kanbans consists of three pallets of each component. The kanbans at the vendor site will be two (five minus three) pallets of the sporadically demanded component and one (four minus three) pallet of the consistently demanded component. This results in the hypothetical Kanban shown in Figure 3.6 (for the sporadically demanded component) and 3.7 (for the consistently demanded component).
Operation of the kanban occurs when a pallet is required for production at the Annesley site. The pallet is removed from the Kodak kanban. At a predetermined time the number of pallets needed from the vendor are counted (from kanban cards or empty inventory spaces) and the order is placed. Material from the vendor kanban replenishes the Kodak kanban. The empty space in the Vendor kanban then triggers production of additional material. In this case, the Vendor MOQ is larger than the signaling quantity. Therefore, the vendor produces the MOQ of three pallets. This results in the amount of inventory at the vendor site expanding beyond the limits of the vendor kanban (to five pallets for Figure 3.7 and four pallets for Figure 3.8). In this situation, another production order will not be created until the excess pallets and a signaling pallet have been consumed.

Prior to describing the impact of the kanban system on component inventory, a review of the advantages the kanban system does and does not provide is useful. The kanban system significantly simplifies the flow of information between vendors and Annesley. This advantage improves performance of the supply chain but is not seen as a reduction in the calculated inventory level. Inventory in the kanban system is reviewed
and ordered on a daily basis. This is different than the ROP system in which an order is placed only when inventory levels fall below the ROP. Since inventories rarely fell below the ROP on a daily basis, the kanban system requires more frequent deliveries of smaller quantities. Both the ROP and kanban system are subject to the vendors MOQ. Therefore, the kanbans have no direct advantage over the ROP system related to vendor MOQ.

Table 3.1 shows the results of simulating the kanban systems in Figures 3.7 and 3.8 with the demand from used in Figures 3.1 and 3.2, respectively. Note that the average inventories of the ROP and kanban systems are not dramatically different. The goal of the kanban system is not to directly decrease the amount of inventory, but rather improve the flow of information and material while creating the correct incentives in the component supply chain.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Sporadic Demand Pattern</th>
<th>Consistent Demand Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ROP</td>
<td>Kanban</td>
</tr>
<tr>
<td>Average Inventory*</td>
<td>26.4</td>
<td>32.0</td>
</tr>
<tr>
<td>Max Inventory*</td>
<td>37.0</td>
<td>42.0</td>
</tr>
<tr>
<td>Stock Outs</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

*Values are divided by average daily demand

3.5: INVENTORY MODEL CONCLUSIONS

Overall the amount of inventory needed to maintain service levels in a max per lead time system is roughly similar to the amount of inventory calculated through a ROP model. However, the max per lead time inventory calculation does provide the advantage of better estimating demand variation. Additionally, a wider range of employees at Kodak understand the calculation.

The power of the kanban is not in the inventory level itself, but in the simplicity of operation. In theory, the value stream of Figure 3.6 could be managed through computerized records if inventory accuracy issues were eliminated. The computer system is replaced by a system in which kanban cards or the inventory itself is the method through which inventory levels are tracked and production decisions are made. Ultimately, service level increases and real inventory levels and obsolescence decrease
due to the increased accuracy of the visual kanban system. Additionally, the need for the
decision maker evaporates. This frees up personnel to focus on more value added
activities such as evaluating kanban sizes or participation in Kaizen events.

The kanban system also incentives the appropriate behaviors in the component
supply chain. At the Annesley facility there is an incentive to better level demand so that
the kanban inventory owned by Kodak decreases. Any improvements in lead time or lot
size translate immediately to inventory reductions for the vendor.
CHAPTER 4: DISPOSAL OF EXCESS INVENTORY

A common issue in inventory management is accumulation of excess inventory. This can occur for a variety of reasons. Some relevant causes for the Annesley facility include redesign of products, reduction in demand for a product, forecast errors, record keeping errors, and introduction of new products.\(^{17}\)

Several approaches and solutions to the problem of excess inventory have been developed. A solution was found to the excess inventory problem under the assumption that demand is both known and constant.\(^{18}\) Later, the methodology was improved upon to provide a method to determine if inventory is excessive in the face of demand variability.\(^{19}\)

4.1: EXCESS INVENTORY CALCULATION OVERVIEW

All of the methods of determining if inventory is excessive occurs under the same basic premise. There is a quantity of inventory which will have to be held (before being consumed or sold) for sufficient time that the cost of holding of the inventory is equal to the cost of disposal. Inventory in excess of this quantity should be disposed.

4.1.1: Optimum Stock Level without Demand Variability

The method of determining the optimum stock level with constant, known demand begins with the following formulation of the problem:

\[
\text{Holding Net} = \text{Salvage Value} + \text{Holding Cost} - \text{Repurchase} - \text{Reorder Cost}
\]

(Equation 4.1)

With this formulation of the problem, any inventory for which Holding Net is greater than zero should be purged. This description of the problem was solved for two cases, one that does not consider the time value of money and one that does.

The most significant assumption made in this method is that demand is constant and ongoing. In addition to demand, the parameters of current unit price \((P)\), ordering


cost \((C)\), and holding cost fraction \((h)\) are assumed to be constant. Unit price is never discounted (i.e. no incentives are provided to buyers for purchasing slow moving inventory). Additionally, stock outs are not permitted and space and capital are unconstrained. The solution assumes that the inventory is not perishable. While several of these assumptions do not hold for the Annesley facility (demand is not constant and ongoing demand may not exist), the formulation does provide a good starting point for analyzing inventory levels.

In the case of the no time value of money, the formulation of the problem described above reduces to (variable definitions are in Appendix A):

\[
    t_o = \frac{P - SV + C/Q}{P \cdot h} + \frac{Q}{2\lambda}
\]

(Equation 4.2)

The outcome of the solution is an optimum time supply \((t_o)\) of inventory retained. The amount of inventory to hold based on this formulation is determined by multiplying the demand rate by the optimum time supply. Any inventory in excess of this quantity should be purged.

Solution of the problem with inclusion of the time value of money is significantly more involved. The simplified formulation takes on the following form:

\[
\left(\frac{Ph\lambda - Ph\lambda t}{2}\right) e^{-it} + \left(\frac{PhQ}{2} + \frac{PQ(n-i) + C(n-i)}{e^{(n-i)Q/\lambda} - 1}\right) e^{(n-i)t} - SV \cdot \lambda - \frac{Ph\lambda}{2i} = 0
\]

(Equation 4.3)

The \(t\) that satisfies this equation is the optimum time supply of inventory. The optimum time supply cannot be found analytically from this equation. However, Newton’s method has been successfully applied to the equation to determine \(t_o\).

4.1.2: Optimum Stock Level with Demand Variability

This methodology to find the optimum stock level that considers demand variability compares the expected future value of a sale of an item with its immediate salvage value and expected cost of holding the material in inventory. If the salvage value of an item exceeds the discounted future sale price of the item minus the holding cost of the item than it should be disposed of. Formally, this can be represented as:
Salvage Value = Expected, Discounted Sale Value – Holding Costs

(Equation 4.4)

To complete this analysis several assumptions were made. The first assumption made in the analysis is that the sale of a given item can be represented a Poisson distribution. Another assumption of this method is that the items in question are not perishable (in his paper, Rosenfield discusses the impact of perishability, but it was not considered here because it is not relevant to Annesley’s components). Finally, there is an assumption that there is no cost of stock out.

This methodology provides significant advantage over the methodology discussed in section 4.1.1 due to the inclusion of demand variability. The formulation of the problem reduces to the following equation which provides the optimal quantity of inventory to retain \((n^*)\):

\[
n^* = \frac{\ln((V + h/i)/(A + h/i))}{\ln(M(i))}
\]

(Equation 4.5)

In this equation \(M(i)\) is the moment generating function of the time between demand events. The equation can be further reduced by assuming that a Poisson distribution represents demand:

\[
M(i) = \frac{\lambda}{\lambda + i}
\]

(Equation 4.6)

With this assumption, the optimum stock level equation reduces to:

\[
n^* = \frac{\ln\left(\frac{SV + \frac{h}{i}}{\frac{A + \frac{h}{i}}{\lambda + i}}\right)}{\ln\left(\frac{\lambda}{\lambda + i}\right)}
\]

(Equation 4.7)

Note that equation 4.7, which includes demand variability, is considerably simpler than equation 4.3, which does not. The reduction in the number of terms of equation 4.7 is driven by the assumption that there are no repurchase (the assumption of ongoing demand in equation 4.3 requires eventual repurchase of material) or reorder costs.

4.2 Optimum Inventory Level Application

The majority of the assumptions made in the solutions to the optimum stock level are appropriate. Annesley’s components are not perishable. The component prices,
ordering costs, and holding costs are generally constant. Additionally, constraints on space and capital are irrelevant to the solutions in Annesley’s case.

However, two assumptions do present cause for concern. Both solutions assume that there is no risk or cost of stock out. In the case of the Annesley facility this is not true. Treatment of the demand pattern in both solutions also deserves further consideration. The end item demand entering the Annesley facility is certainly not constant. Further, the Poisson distribution does not represent demand in the EAMER region well. To deal with the discrepancies between the assumptions and the reality of Annesley’s situation, the outcome of the models was considered in light of the current expected sales situation.

Since the components delivered to the Annesley facility are fairly specific, the salvage value of the components is zero. The sales force does generally not consider inventories of components, so future discounts to move an item are unlikely. Thus, the value of each sale as a fraction of the original sales price can be set to one. Inventory levels are evaluated on an item by item basis. However, the inventories which may exist in excess are often ordered at the same time as many other items. Therefore, there the cost of ordering is zero. Inflation is set to zero, since it is accounted for in the discount rate (i).

This allows reduction of the equation 4.2 (constant demand, no time value of money) to:

\[ t_o = \frac{1}{h} + \frac{Q}{2\lambda} \]  \hspace{1cm} (Equation 4.8)

In this case the optimum stock equation becomes a function of the holding cost of inventory, component batch size, and demand. Using the same parameters, equation 4.3 (constant demand, time value of money) reduces to:

\[ \left( \frac{Ph\lambda}{2i} - \frac{Ph\lambda}{2} \right) e^{-it} + \left( \frac{PhQ}{2} + \frac{PQ(-i)}{e^{-iQ/\lambda} - 1} \right) e^{(-i)t} - \frac{Ph\lambda}{2i} = 0 \]  \hspace{1cm} (Equation 4.9)

The optimum time supply of inventory is found by solving equation 4.9 for t. Finally, the parameters discussed above applied to the uncertain demand solution (equation 4.7) yield:
\[ n^* = \frac{\ln\left(\frac{h}{i}\right)}{\ln\left(\frac{\lambda}{\lambda + i}\right)} \]

(Equation 4.10)

The amount of slow moving inventory to maintain is reduced to a function of the average sales of the product, the holding cost of the inventory, and the discount rate.

All three of the methodologies to determine the optimal inventory level were used to calculate recommended inventory levels for a component at the Annesley facility (Figure 4.1). The constant demand solution that does not consider time value of money was expected to recommend retaining the most inventory. The results matched this expectation as the constant demand, no time value of money solution retained the most material. Of the solutions that consider time value of money, the variable demand solution was expected to recommend more inventory than the constant demand solution. For very low demand levels (scaled demand below 0.5) the constant demand with time value of money solution did recommend retention of the least material. However, the variable demand with time value of money solution recommends maintenance of the least material for large demand values. The ongoing demand, and consequent inventory repurchase, of the constant demand case is believed to cause this unexpected result.

Figure 4.1: Recommended Inventory Levels
When applying the calculations, the results need to be carefully analyzed. First, the solutions should be assessed in light of expectations of future demand (i.e. launch of a promotion). If information about future demand does not exist the actual amount of inventory to maintain should be weighted toward the uncertain demand solution. Then the actual solution should be considered in terms of the physical impact. For instance, the formulaic answer may suggest discarding one half of a full pallet of non-stackable inventory. However, since this does not free up space and will likely increase difficulty in physical inventory checks this action does not decrease inventory maintenance cost. In this case, the appropriate action is to retain the full pallet.

To implement the inventory reductions at Annesley, first the errors in inventory management systems had to be corrected. To correct the inventory management system all of the Kodak stock at the hub (this stock was responsible for a majority of the inventory accounting errors) was physically counted. Any discrepancies between the inventory records and the physical count were then resolved.

In the physical count, a portion of the stock held at the hub was found to be obsolete. This inventory was immediately scraped. Additionally, many of the components held at the hub were to be replaced by new components due to a rationalization project. In the case of these components, the level of inventory retained was capped by the maximum expected usage prior to implementation of the rationalization project.

4.3: Excess Inventory Disposal Conclusions

This chapter discussed three methods of calculating the optimal inventory level. All three provide results that are good starting points for determining the appropriate inventory levels to maintain. With these results, analysis of the demand and physical situation of the inventory provides a reasonable estimate of the optimal amount of inventory to maintain.

Several aspects of Annesley’s environment including redesign of products, reduction in demand for a product, forecast errors, record keeping errors, and introduction of new products caused the excess inventory. Elimination of the excess
inventory was a necessary step in getting out of the hub. The record keeping errors are the issue that the Annesley facility has the most control over. Elimination of the hub and installation of kanban inventory systems will do a great deal to improve the accuracy of inventory records.

Yet many challenges to maintain optimum stock levels remain. Discussion of the redesign of products, reduction in demand for a product, and introduction of new products is in the incentive alignment section of Chapter 5. Since some of these issues have not been resolved, a system for ensuring excess inventories do not accumulate must be created. The Material Review Board section of Chapter 5 contains discussion of such a system.
CHAPTER 5: OPPORTUNITIES FOR FUTURE WORK

During the course of this project several improvement opportunities for Kodak that fell outside the scope of the project to exit the hub were discovered. Because these opportunities represent large potential savings for Kodak and relate to this project they will be discussed in the following paragraphs. Specifically, the opportunities discussed include improvement and alignment of sales, marketing, and manufacturing incentives, development of a group responsible for identifying and disposing of excess inventory, and assisting suppliers with implementation of lean principles.

5.1: SALES, MARKETING, AND MANUFACTURING INCENTIVES

Like most publicly traded companies, Kodak’s incentives revolve around metrics recorded at the end of the business cycle (i.e. end of fiscal quarter and year). While these incentives improve shareholder return in the short term, their misalignment can result in unnecessary cost over the long run.

The sales organization is responsible for meeting the business cycle sales targets. The sales group consistently attains the desired sales rate. Unfortunately, these sales follow the all too common hockey stick pattern shown in Figure 5.1. The increase of sales at the end of the period occurs by providing favorable terms to wholesale and retail buyers.

For a sale to be counted in the current period, the product must be delivered to the customer prior to the end of the period. Therefore, the hockey stick sales pattern places a particularly large strain on the manufacturing organization at the end of the period. Figure 5.2, which shows the estimated total demand in production at the Annesley facility over the course of a business period, illustrates the impact of the sales pattern on the manufacturing organization.
Figure 5.1: Hockey Stick Sales (Scaled) Pattern of the EAMER Region over One Business Cycle

![Graph of Hockey Stick Sales Pattern](image)

Figure 5.2: Estimated Demand (Scaled) in the Annesley Facility over One Business Cycle

![Graph of Estimated Demand Pattern](image)

The responsibility of maintaining Kodak’s market share falls on the shoulders of the marketing organization. To meet their market share objectives, marketing develops
promotional products and display units. The result of these activities is an increase in portfolio size and consequent difficulty managing inventories through the supply chain. Since promotional items are often tagged to a specific time period (i.e. an Olympic promotion) and are produced on a forecast, the distribution chain can get stuck with outdated promotional inventory that must be scraped or returned to the manufacturing organization for rework.

The manufacturing organization is required to meet period end inventory targets. Period end inventory levels can be decreased by lowering the production rate. Note that the incentive for production to lower manufacturing rate is directly opposed to what the sales organization would like manufacturing to do at the end of the business period but aligns well with actual sales rates at the beginning of the business cycle.

A system dynamics model (Figure 5.3) demonstrates the interaction of the incentives and their impact on the EAMER region. The model includes the key incentives for the Manufacturing, Marketing, and Sales organizations as well as two key metrics for the EAMER region – production cost and customer service.

To effectively demonstrate the impact of the incentives, the inventory in the distribution chain was split into two stocks, salable inventory and non-salable inventory. Promotions, while increasing the sales rate, have the undesirable outcome of creating non-salable inventory. This occurs because promotional demand is forecasted, but not all promotions are successful. The material left over from a promotion is difficult to sell outside of the promotion. Therefore, reworking the non-salable inventory is the most common course of action. Unfortunately, there is not a well defined process for the rework to occur, which results in much of the non-salable inventory remaining in the distribution chain for undesirable lengths of time.

In practice, there is no distinction in the distribution chain between salable and non-salable inventory. Therefore, manufacturing’s inventory level target is compared against the sum of the salable and non-salable inventory. The inventory target is achieved by moderating the manufacturing rate. Since only the salable inventory is exiting the system (through sales), the level of salable inventory can drop significantly (non-salable inventory can be considered static over short time periods). This places the customer service level at significant risk.
The combination of all the effects can result in low manufacturing rates early in a period to decrease the total inventory in the distribution chain. As the period end nears, the sales rate increases and often the quantity of salable inventory is insufficient to maintain customer service. To overcome the issue of reduced customer service (which generally results directly in lost sales), manufacturing quickly ramps up production. This large change in production rate has many costs, the most significant of which are overtime and material expediting costs. This behavior also causes many of Kodak's component suppliers to carry additional inventory to respond to request for expedited material, thereby increasing costs throughout the Annesley component supply chain.

By examining the incentives from a system wide perspective, Kodak may be able to gain alignment among the various organizations. Some potential incentive changes might include penalizing the sales force for inconsistent sales patterns, placing the cost burden of non-salable inventory rework on the marketing group, or combining inventory and production cost metrics into a single measurement. These changes would likely meet
considerable political and cultural resistance, but could result in substantial savings and improved customer service in the EAMER region.

5.2: MATERIAL REVIEW BOARD

One of the necessary steps for removing the hub from Annesley’s component supply chain was to identify and dispose of excess and obsolete inventory. This was necessary because no one had previously been responsible for this action and there were no clear procedures. Elimination of the hub and introduction of kanbans will decrease the formation of excess and obsolete inventory by improving inventory record accuracy. Despite this improvement, excess and obsolete inventory creation will continue through redesign of products, reduction in demand for a product, forecast errors, and introduction of new products.

To ensure that excess and obsolete inventory do not amass again, formation of a material review board is recommended. This board must periodically review each component to ensure that all existing inventories are necessary to maintain production activities. By undertaking this activity the board will allow component service levels to be maintained while minimizing inventory holding costs.

5.3: ASSISTING SUPPLIERS WITH LEAN IMPLEMENTATION

The response of a supplier when shown the positive impact that implementation of lean had created at Annesley facility responded that Annesley’s lean efforts were significantly expensive to the supplier. In actuality, the suppliers cause for concern most likely relates to their accounting system and not to their actual costs. Yet, the perception that frequent changeovers and small lot sizes are expensive does exist. Unfortunately, this perception is hurting Kodak and Kodak’s suppliers. For instance, most of the kanban systems developed at Annesley site are not true kanbans. This is because the process a kanban controls should only produce product to replace the product the customer consumes, which is often less than the suppliers MOQ. In an extreme case a request to decrease lot sizes at one supplier was met with the response that this was prohibitively expensive, despite the fact that the lot size was in excess of the amount of inventory the optimal inventory calculations of Chapter 4 would recommend maintaining.
To break the lean stigma, Kodak should help suppliers understand the principles and benefits of lean. To accomplish this, suppliers should first be invited to Kodak to partake in Kaizen events at the Annesley facility. Following this, Kodak’s lean experts in the KOS office should be dispatched to assist suppliers with Kaizens at the supplier’s site. This process will likely take years if not decades, but is necessary if Kodak wishes to continue to drive down manufacturing costs.

One requirement for Kodak to disseminate lean principles to their suppliers is that long term agreements, formal or informal, must be created. Kodak’s suppliers will be very hesitant to take the lean leap if they do not know if they will be producing for Kodak next year. Conversely, management at the suppliers will be willing to take greater risks if they are certain that they have Kodak’s long term support and partnership. Additionally, Kodak must ensure that suppliers are rewarded monetarily for their lean efforts.
6.1: HUB EXIT RESULTS

Installation of kanban systems occurred for many of the critical components over the course of the project. These kanbans functioned well once the vendors and Kodak’s personnel gained familiarity and experience with the kanban rules and operation. The sizing of the kanbans by the max per lead time method has been well received by the personnel responsible to managing inventory and has proven to be successful to the degree that historical stability of demand will allow. Although no data is available to explicitly demonstrate this, the kanbans did seem to improve the availability of material to the shop floor. Additional components continue to be transitioned to kanban systems as Annesley continues the conversion to lean manufacturing.

The excess inventory calculation and analysis identified a large portion of the unnecessary inventory maintained at the hub for disposal. The remaining inventory was consolidated and transported to the Annesley facility. As much of this material as possible was placed alongside the production machines that will consume it. The material that not placed line side was moved into area vacated by outsourcing of plastic components. As the component supply to the Annesley facility becomes leaner, the inventory in this area will diminish.

Shortly after completion of, and due in large part to, the work described in this thesis Kodak was able to exit the hub. By implementing kanbans and eliminating the obsolete and excess inventory, component inventory quantities were reduced to a level that could be housed at the Annesley facility. A dramatic dichotomy can be seen between the photos of the hub prior to the project (Figure 1.4, Chapter 1) and the photos of the hub and of the Annesley site during the hub exit (Figures 6.1 and 6.2).
Figure 6.1: Empty Racks at the Hub During Exit

Figure 6.2: Inventory at Annesley During Hub Exit
Ultimately, the project to move out of the hub will save Kodak and Kodak’s suppliers a considerable amount of money. The most obvious savings from the project results in the elimination of the contract with the third party logistics supplier. By sending material directly from vendor sites to the Annesley facility the transportation costs in the component supply chain will decrease. The simplified material and information flows in the post-hub world will reduce inventory record errors. Therefore, less time, effort, and resources will be spent expediting components and managing inventory excesses. Inventory levels and subsequent holding and obsolescence costs will continue to decrease.

Despite all of these improvements, significant opportunities still exist in the component supply chain of the Annesley facility. By assisting suppliers with the implementation of lean, Kodak can reduce the lead times and lot sizes of suppliers. Implementation of a material review board will ensure that the cost incurred by Kodak for inventory management will have the greatest possible impact on customer service. Finally, alignment of incentives within Kodak’s EAMER region will reduce the strains on the manufacturing organization and Kodak suppliers.

The exit from the hub and the implementation of the potential improvements in the prior paragraph will allow Annesley to continue to slash costs through the supply chain. This will allow Kodak to gain the greatest possible profit from film sales in the EAMER region and ultimately fuel the strategic initiatives that represent the future of Kodak.

6.2 Conclusions

Several tools, including SIP modeling, kanbans, and optimal inventory calculations were applied to the problem of hub exit. Each of these tools was crucial in the hub exit project. The following paragraphs provide a summary of the tool’s impact.

The SIP model highlighted the issue that inconsistent lead time requirements placed on the Annesley facility. The results of the modeling exercise demonstrated the dynamic environment in which Annesley exists and highlighted the need for the component inventory systems to maintain this flexibility.
The kanban system proved to be very powerful in the hub exit project. The greatest attribute of the kanban system is its simplicity. Once trained, operations personnel can easily see how the system functions and how their actions impact material flow. Additionally, the max per lead time concept used to size the kanbans was much better understood than the calculations for the previously employed ROP model. The greatest advantage of the kanban system for the Annesley facility is the reduction in inventory record errors.

Several methods for determining the optimal inventory level to retain exist. Although the assumptions of the calculations do not exactly match reality, they provide good reference points for inventory retention. The calculations, used in concurrence with expectations of future demand and the physical state of the inventory, can directly improve the bottom line of a corporation through disposal of excess inventory.
7: BIBLIOGRAPHY


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APPENDIX A: SUMMARY OF ABBREVIATIONS AND SYMBOLS

A  Expected sales value as a percentage of the original value
C  Ordering cost
DDLT  Demand during lead time
E  Inventory overstatement (percentage of total inventory)
EAMER  European, African, Middle Eastern, and Russian
h  Holding cost of inventory
i  Discount rate
k  Inventory safety factor
LT  Replenishment lead time
M  Moment generating function of time between demand events
MOQ  Minimum order quantity
n  Inflation
n*  The number of items to maintain in inventory
P  Unit price
Q  Order quantity
r  Cost of holding inventory (percentage of inventories cost)
ROP  Reorder point
S  Promised lead time
SS  Safety stock
SV  Salvage value
T  Production time
t_o  Optimum time supply
\lambda  Average sales per year
\sigma  Standard deviation