Implementation of Lean Manufacturing Techniques to the Internal Supply Chain of an Automotive Assembly Plant

by

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Submitted to the Sloan School of Management and the Department of Mechanical Engineering in partial fulfillment of the requirements for the degrees of

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Abstract

The world automotive manufacturing environment has become continuously more competitive over the past two decades. During the 1980s, in the United States, the U.S. domestic automotive manufacturers were forced to improve their manufacturing operations with regards to quality, leadtime and flexibility, using lean manufacturing methods, in response to foreign competition. A similar focus on improving operating efficiency using lean manufacturing is now emerging in European car markets.

This thesis focuses on the implementation of lean manufacturing techniques to improve the operational effectiveness within the supply chain of a European automotive final assembly plant of an U.S. based automotive manufacturer. The focus of the study consists of three major facets of the internal supply chain: linefeeding improvements, inventory control policies, and improvements in the material receipt and storage methods.

The reason for pursuing this project was to support the drive toward improving the operational effectiveness by implementing lean manufacturing initiatives. In parallel with this project, several other lean manufacturing initiatives were also in process, such as the Ford Production System (FPS), that helped to support this project. All of these initiatives were being undertaken to improve the profit potential within the Cologne assembly operations.

The goal of this research was to investigate methods of cost reduction by doing the following actions:

- establish optimal inventory levels that will decrease working capital requirements while increasing service levels,
- eliminate part delays throughout the system,
- improve the quality of parts within the system by "lowering the level in the river" and
- reduce the non-value added steps in the material replenishment process.
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The approach to the research began by gathering information about the current system, such as the material demand and supplier leadtime. To establish the optimal inventory requirements, the average and standard deviations of these variables were then used to calculate the inventory needed based on the delivery frequency while accounting for the variability. The current internal and external supply chain logistics were evaluated to determine the most efficient routes to eliminate delays. Within the internal logistics systems, temporary storage areas for material buffers, called marketplaces were planned and implemented. A marketplace consists of clearly defined storage locations for each part with visible markings for minimum and maximum allowed inventory levels that helped better organize and control material flow. The new marketplaces and material handling routes were implemented in several areas within the assembly plant.

The results of this research is strategy that a manufacturing company can use as guidelines for improving the inventory control policies and material flow within its worldwide assembly operations. The result of shifting to the proposed inventory control policy would be annual savings of around $200,000 and a one-time savings from inventory liquidation of around $1,000,000. The total savings due to the new material handling routes were unable to be determined. Additionally, several observations regarding difficulty of implementation of new manufacturing methods on a traditional mass production plant will be discussed.

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Chapter 1: Introduction

1.1 Statement of the Problem

The world automotive manufacturing environment has become continuously more competitive over the past two decades. During the 1980s in the United States, the U.S. domestic manufacturers were forced to improve their manufacturing methods with regards to quality, leadtime and flexibility. The primary driver for this change in the U.S. was the entrance of the Japanese competitors with more efficient manufacturing processes.

Volumes of research have been written on how the Japanese competitors were able to produce cars more efficiently using "lean manufacturing" instead of the traditional mass production techniques typically used by most Western automotive manufacturers in the 1980s. One of the most famous books on the subject, The Machine That Changed the World (Womack et al., 1991) led many U.S. auto manufacturers to put together their own lean manufacturing programs in response to this competitive threat. At many companies the tenets of the Toyota Production System, considered the first lean manufacturing system, were rewritten into corporate manuals resulting in a new set of production methods for the firm, such as the Ford Production System.

In Europe, the same competitive forces were not fully in place during the 1980s. However, the Japanese automakers are now beginning to establish manufacturing plants throughout Europe to make their models more competitive for the European market in terms of price and features. Their entrance is significantly increasing the competitive nature of the market, particularly in the smallest car segments. This competitive threat is one of the reasons that U.S. automotive companies in Germany are beginning to try to implement lean manufacturing processes to maintain a competitive edge.

For the Ford Cologne facility, the competitive pressure is very strong since the model built at Cologne, the Fiesta, competes directly with a number of the new Japanese imports. Additionally, the labor
costs in Germany have historically been very high, which, combined with the inefficiencies of mass production, causes the total manufacturing cost to be higher than that of more efficient competitors.

The result, of the increased competition, is that most of Ford’s facilities in Europe are undergoing some form of lean manufacturing implementation to reduce cost, become more flexible and improve quality. At Cologne Assembly, the Material Planning and Logistics manager was interested in implementing lean manufacturing techniques to the material flow process. To meet this need, he submitted a request to the Leaders for Manufacturing program at MIT for a research project.

The Cologne plant was a well-established mass production plant that was ripe for change. The material flow process was filled with waste. One example of waste was the inventory levels of the component parts. The stock levels were high in the plant for some parts; however, there were stockouts of other parts. Another problem was that the Cologne plant had was that the material delivery system lacked standardized methods. As a result, there were expeditors that continuously rushed necessary parts to the line when needed. Additionally, wagonloads of material were randomly parked in most of the aisles and at the receiving docks. A third problem was that there were no standardized systems for part delivery or storage that were visually obvious to the operators. Finally, material handling's customer, the assembly line, was not served with the right part at the right place at the right time. The focus of this thesis is to explain the work that was performed to improve the situation of the Cologne plant with respect to these problems within the material flow system.

1.2 Project Scope and Objectives

The scope of this project was to redefine the material flow and control methods for the trim line area of the Ford Cologne assembly plant. The trim lines encompassed the assembly operations for most of the interior cabin, the motor compartment and the hatchback area of the automobile. The project primarily consisted of three main objectives pertaining to the material flow within this area of the plant:
• Analyze and improve the methods how the material was delivered to the line,
• Analyze and improve the temporary storage methods of the material and
• Evaluate the inventory management for the plant.

The objectives of the project were developed in conjunction with the Materials Planning and Logistics manager for the plant along with the Material Services manager. The result of these objectives was to reduce the levels of inventory, where applicable, to the management goal of 1.4 days on average. However, through the course of the research it was determined that this level was not necessarily appropriate. An additional result desired was to implement a more “visual” system for inventory flow and control. Finally, there was a need to better meet the requirements of the customer, the assembly line, by delivering the right part at the right time in the right quantity.

1.3 Project Background

The Cologne Niehl Assembly operation is a traditional mass production facility. The plant has not implemented many of the aspects of lean manufacturing that would help it achieve operational excellence to become more competitive in the world marketplace. Ford is just beginning to use the Ford Production System, or FPS, to educate and implement the lean manufacturing techniques developed by Toyota at its plants around the world. However, this process was just beginning in Cologne in 1998 during the course of this research.

One of the principle elements of FPS implementation is the realization of Synchronous Material Flow, or SMF. SMF is the term used to describe a pull-based, continuous material flow system based on Just-in-Time concepts such as kanban cards and single piece flow. SMF encompasses all of the aspects of the material flow both inside the plant as well as deliveries to the plant from suppliers. Some of the goals of SMF are to make the material flow more visible, to gain more control over the levels of inventory in the plant and to improve the quality of the materials by making problems more visible.

Upon arriving at the Cologne plant, only the basic SMF training had taken place with the employees and SMF methods were not in use at that time. Unfortunately, the plant lacked regular systems
for the material delivery to the line and temporary storage locations. Additionally, the plant was plagued with inventory stockouts of some parts and excessive inventory levels of other parts. For example, based on one analysis from 11 August 1998, $30.5 million was the total value of the inventory in excess of three days stock and more than $1,000 in inventory value. To fight this problem of excess stock, personal letters were written to request the suppliers stop shipping these parts.

Another problem in the plant was the fact that there was not a regular storage system, resulting in problems locating parts. The storage locations that did exist were not visually clear, which caused a problem with new operator training and with maintaining the appropriate inventory level. The lineside replenishment system consisted of forklift drivers driving up and down the line to identify the necessary parts and search for them because they were stored in haphazard locations. During the shift changes, the next shift operator had to figure out where the last person had left the new parts delivered to him during the last shift. As a result of the problems in the system, additional drivers were required to expedite parts needed by the assembly line. With a more appropriate replenishment system, these expeditors would not be necessary.

1.4 Summary

The Cologne assembly operation was a typical traditional mass production automotive assembly plant. This work documented in this thesis was undertaken to make the plant more cost competitive in the marketplace. This thesis consists of a description of some of the steps taken to implement lean manufacturing techniques to material flow of the Cologne assembly plant and the results of that implementation.
Chapter 2: Project Background

2.1 Background of the Facility

2.1.1 History of the Cologne Niehl Assembly Operations

Ford began manufacturing cars at the Cologne Niehl facility in 1930. The plans for the site were modelled as a scaled down version of Ford's famous River Rouge facility, one of the most renowned landmarks of mass production. In fact, Henry Ford himself laid the cornerstone for the first assembly building at the site. The facility has been through many different car models since that time, and the use for each of the buildings has changed significantly. The current assembly building is approximately 4.6 million square feet. The Cologne assembly plant is Ford's fourth largest, of 53 assembly plants in the world. A detailed layout of the plant is shown in Figure 1.

At the time of this analysis, the Cologne plant was manufacturing the Ford Fiesta in three and five door versions and the Ford Puma, a two-door sports car. The daily production rate was around 1,215 per day. The plant was meeting this demand by running two, 7.5-hour shifts, five days per week. Up until June 1998 the plant produced a third model, the Scorpio. However, due to low demand in the market, this model was discontinued. The elimination of this model allowed extra room within the plant to improve the plant layout in terms of material flow and storage since part of the Scorpio assembly lines were left vacant (identified as Scorpio Trim in Figure 1).
Köln Montagehalle 'Y'

Figure 1: Cologne Assembly Building Layout
2.1.2 Current Improvement Projects

Several other initiatives, directly related to lean manufacturing, were in process to improve the production methods within the plant prior to this analysis. First, during 1998 the centralized packaging group for Ford of Europe has been working to implement recyclable packaging for all components. Second, there was a pilot implementation of the Ford Production System, or FPS, on one line in an attempt to implement lean manufacturing techniques to the Cologne facility. Finally, Cologne was in the process of implementing a Lead Logistics Provider, or LLP, to control all of the external logistics from the supplier plants. Each of these improvement efforts is described in more detail below.

The recyclable container project was underway during late 1997 and throughout 1998. The project strategy was based upon using a pool of leased containers of standard shapes that can be used for packaging instead of cardboard. The container pool was managed by an external logistics company to circulate the containers between Ford and its suppliers’ sites. Following the conversion, the majority of the parts came into the Cologne plant in either $1.0 \text{ m}^3$ recyclable containers, called FLCs, or one of three sizes of smaller standard containers called KLTs, both shown in Figure 2. This conversion in packaging allowed for several improvements in material handling. First, the lineside racking could be standardized for the given box sizes throughout the factory. Second, labeling of the parts could be consistently applied across the full range of boxes. Finally, Ford saved a large amount of money from eliminating the disposal of cardboard.

Figure 2: KLT and FLC Containers
The second large-scale initiative underway at Cologne during 1998 was the Initial Application Area, or IAA, of the Ford Production System. The IAA chosen for the FPS initiative was the plant's door assembly line, or doorline, since it was considered the bottleneck of the plant. The FPS training and implementation began in early 1998 with the objective to create a model area of the plant for others to follow as an example. The employees on the doorline went through extensive training on the FPS methods of standardized work, waste reduction, quality control, synchronous material flow, and other lean manufacturing topics.

One improvement that the FPS team implemented was eliminating most of the high vertical storage racks at the lineside to make the assembly line more visible to all the operators and management. Another improvement was the implementation of a kanban card replenishment route for small parts between a marketplace to the line with a regular route time of two hours. Additionally, the operators were trained in the 5 S's (sift, sort, sweep, standardize, spic & span in FPS terms) to improve the organization and cleanliness of the plant. The initial FPS implementation was projected to reach the implementation targets during the second half of 1998. In December 1998, the project reached most of the specific objectives in terms of quality, cost, and work procedures.

A third initiative underway at Cologne during 1998 was the Lead Logistics Provider, or LLP, initiative. The LLP was in the process of being evaluated during 1998 to try to control the flow of external material from the suppliers. The LLP was a company contracted to improve the control of the external logistics to the plant. Some of the LLP's work was to determine and verify the packing lists of the trucks at the supplier according to the scheduled daily production. The truck would then be monitored throughout its standardized route in order to meet a defined time window at the assembly plant. Additionally, the routes would be rationalized based on efficiency and integrate concepts such as direct delivery and "milk run" consolidations. Using the LLP effectively would result in more control on the inventory levels in the pipeline and should result in lower costs resulting from stockouts and premium
freight costs. The objective the LLP team was targeting was a reduction in annual freight costs by 19.4%. The primary savings would result from reductions in normal freight costs by improving transport utilization and increasing control of the shipments from each supplier.

Each of these other initiatives had directed attention to material flow process, which helped to focus the need on improving the material flow across the plant. Particular aspects that we noted for improvement were to make the system more visual and to standardized methods across the plant. These aspects led to initiating the steps taken to improve the material flow process during the second half of 1998 at the Cologne assembly plant described in this thesis.

2.2 Approach Used for the Analysis

The approach used for the analysis of the system was based on investigating the various aspects of lean manufacturing, particularly within the Toyota Production System, which are described further in Section 2.3.2. The Cologne plant was evaluated against these lean manufacturing work methods and then various aspects of them were implemented at the site during the study.

The first step in the analysis was to understand how the current system worked. The Cologne plant is quite large and it took time to understand the material flow within the facility. Additionally, it took time to investigate the current material control system, which included people such as the stock counters and the use of the Direct Data Link (DDL), which was a form of Electronic Data Interchange (EDI) with the suppliers.

The second step in the analysis was to gather data about the parts that were involved in the process. There are over 3,500 part numbers that could be used in the plant on any given day. The locations of these parts are spread out over a very long assembly line. There was a small team of workers

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1 data taken from a presentation of the preliminary analysis of the joint TNT and Ford Lead Logistics Provider Team to the Cologne plant management, 29 October 1998.
that helped to document the location of each part along the assembly line. Additionally, the team gathered
data for each of the parts according to packaging type, quantity per container and container size.

The next step was to gather data from the production control database. Database queries were
developed to find data for the daily demand each part, the length of travel time from the supplier, the
delivery frequency of the part and the current inventory level of each part.

The fourth step in the analysis was to use the information gathered to predict the optimal
inventory levels for each part using the Base Stock Model. These levels were calculated based on the
historical average and standard deviation of both the part demand and the leadtime of the supplier.

The final step was to implement control systems for the shop floor to make the delivery of
material more efficient. Standard delivery routes for the material handlers were implemented.
Additionally, temporary storage buffers of parts, called marketplaces, were established. Within the
marketplaces, each part had only one particular place and the location of each part was marked. Each of
the locations was also documented with the optimal inventory levels that were clearly marked as Min and
Max. Additionally, a first-in-first-out flow of material was established within the marketplaces. The
marketplace and material flow concepts are explained in more detail in Chapters 5 and 6, respectively.

2.3 Overview of the Research Findings

2.3.1 Problems with Mass Production

The problems at Ford’s Cologne assembly plant are typical throughout the traditional mass
producers in the auto industry. The situation at the Cologne plant is similar to that noted at the GM
Framingham, Massachusetts assembly plant described in The Machine That Changed the World, the book
that defined some of the basic tenets of lean manufacturing. The description in the following passage was
based on a tour to the GM plant in 1986, however, the situation is virtually identical to that found in
Cologne in 1998.

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On the plant floor, we found about what we had expected: a classic massproduction environment with its many dysfunctions. We began by looking down the aisles next to the assembly line. They were crammed with what we term indirect workers - workers on their way to relieve a fellow employee, machine repairers en route to troubleshoot a problem, housekeepers, inventory runners. None of these people actually add value, and companies can find other ways to get their jobs done.

Next, we looked to the line itself. Next to each work station were piles - in some cases weeks' worth - of inventory. Littered about were discarded boxes and other temporary wrapping material. On the line itself the work was unevenly distributed, with some workers running madly to keep up and others finding time to smoke or even read a newspaper. In addition, at a number of points the workers seemed to be struggling to attach poorly fitting parts to the Oldsmobile Ciera models they were building. The parts that wouldn't fit at all were unceremoniously chucked in trash cans. (Womack, Jones & Roos, 1991, p. 78)

Many of the elements of the Framingham plant are typical to mass production plants. The 1987 analysis revealed that Framingham had 2 weeks worth of inventory compared to 2 days on hand at GM's NUMMI joint venture with Toyota, a well known lean manufacturing site (Womack et al., 1991, p. 83). At Cologne in June 1998, the inventory on average was around 5 days. The excess inventory is a drain of capital from the firm. It is only necessary in order to cover up variation and quality problems due to poor planning and lack of continuous improvement. The excess inventory also typically hides quality problems. The defect rate of the Framingham plant was nearly twice as high as NUMMI at 1.35 versus 0.45 defects per car. The excess workers in the aisles were due to the fact that the rigorous union contracts kept workers from performing multiple roles in the plant which hindered flexibility and continuous improvement. Additionally, the excess workers added to the overall 31 labor hours needed per car compared to 19 at NUMMI. The list of excess wasted resources could go on and on.

The term lean production was coined because it used less of everything compared to mass production. According to Womack et al. (1991), it uses half the human effort in the factory, half the investment in tools, half the manufacturing space and half the engineering hours to develop new products while still resulting in fewer defects and greater variety in the product. The efficiencies can clearly be seen in the comparisons of NUMMI, a typical lean plant, to Framingham, a typical mass production plant.
These parallels can be extrapolated to Cologne, another typical mass production plant that is somewhat better than GM’s Framingham plant in 1987.

2.3.2 Tenets of Lean Manufacturing

Lean manufacturing is the generic term to denote the practices found in the Toyota Production System, or TPS. Taichii Ohno and Eiji Toyoda created TPS in the 1950's to help Toyota cope with the significant capital shortage within the company (Womack et al., 1991, p. 49). Many have documented the key aspects of the Toyota Production System that enable it to yield system improvement and lead to a more optimal use of resources. (Womack et al., 1991; Shingo, 1989; Monden, 1998) The first is elimination of waste from the system. A second is set up time reduction. A third is balanced and level production. Finally, the well-known Kanban and Just-in-Time systems can then be established.

The cornerstone of the Toyota Production System is the elimination of waste. In general, there are seven basic kinds of waste that can typically be identified in any system (Shingo, 1989, p. 191):

1. overproduction,
2. delay,
3. transport,
4. processing,
5. inventory,
6. wasted motions and making defects.

TPS religiously focuses on elimination of waste at each step making processes more productive through continuous improvement activities. Many tools exist to help with waste reduction, such as the 7-step problem solving process and basic statistical process control. Toyota never ceases to target the elimination of waste. It is this discipline that is often lacking in mass production plants.

In many places throughout the Cologne plant, waste can be identified. Overproduction of subassemblies that takes place in big batches from the subassembly groups due to lack of adequate demand information. One example is within the air cleaner assembly cell, where the air cleaners were
assembled in large batches of approximately 40 parts per box. The line used these parts in varying quantities ranging from 16 parts per day to 266 per day. The operators would typically assemble 2 full boxes and then put them on the shelf to wait, regardless of the demand. Additionally, due to packaging decisions, parts waited in large containers for many hours, if not days, at the assembly line.

Approximately 48% of the packaging contained more than one full day's usage of parts. These large boxes required using forklifts and wagon trains to move them. These vehicles exhibit extreme amounts of wasted motion to deliver large boxes full of parts over distances of up to 500 meters due to suboptimal plant layout. In summary, tremendous amounts of waste can be identified to remove by using lean manufacturing techniques.

The second key aspect of TPS is setup time reduction. Setup time reduction is the more generic term for Single Minute Exchange of Dies, or SMED. Used by Toyota, it means that the amount of time needed to change a machine or cell over from one product to the next is continually reduced. By reducing the setup times, the production process is more flexible and can easily switch production to meet the customer's needs in a short period of time.

The third key aspect of TPS is balanced and level production. These characteristics are enabled by setup time reduction. Balanced production means that the production resources of the firm can share the production equally. This typically means that the product cells in a vertical value chain can share work up and down the chain so that one of the cells does not serve as a significant bottleneck in the production process. For example, assembly operations can be integrated into an upstream cell to alleviate a bottleneck in the process. On the other hand leveled production means that manufacturing can produce in the same product mix sequenced on a consistent and level basis that is consistent with the percentages demanded by the customer. For example, if 10% of the cars demanded by the customer require a sunroof, then every 10th car on the assembly line would be sequenced to have a sunroof. Takt time is the key driver of leveled production. Takt time is defined as the total operating hours divided by the salable quantity of
product, it is the amount of time between successive pull signals for the particular product. Takt time sets the "beat of the drum" for the leveled production.

One of the most major elements of TPS is Just-in-Time (JIT) production. JIT is the ultimate goal of TPS - to make exactly the material needed by the customer in exactly the right quantity, in exactly the right place, at exactly the right time. This type of system can only be realized in a system that has short setup times, where production is balanced and level, and where waste has been driven out of the system. Typically a kanban pull system consisting of cards circulated between the customer and supplier is used to enable JIT. The pull signal for the quantity, place and time is communicated to the supplier by the kanban card. In turn the supplier delivers the material just in time to the customer. The most responsive configuration of this system is single piece flow, however typically the parts are delivered in small lots consisting of several hours of stock.

Each of the key points of the Toyota Production System and lean manufacturing mentioned above are imperative to making the system function together efficiently to meet the customer's needs. The system has many contrasts to typical mass production, which causes a significant challenge during the implementation of the changeover.

2.3.3 Implementation of Lean Manufacturing

Following The Machine that Changed the World, many companies raced to implement their own from of their own lean production system, modeled after the Toyota Production System. Ford developed its own version of lean manufacturing, the Ford Production System, which has been implemented with various levels of success. Based upon the author’s interpreting works from well know researchers in the field such as Monden (1998), Womack et al. (1991, 1996) and others (Black, 1991; Shingo, 1989), FPS seems to encompass many of the elements of the Toyota Production System.

Ford has several successful implementations of lean manufacturing that the author had the chance to visit during the course of this research. The team based approach for machining and assembly at the
Cleveland Engine Plant was highly successful. In terms of inventory reduction and control, their card-based replenishment, or kanban, system had facilitated an estimated $500 million dollars in inventory savings. Another kanban system that was in the process of being implemented at Ford's Saarlouis Germany Assembly Plant was studied during the course of this analysis.

Many other firms have also successfully implemented lean manufacturing techniques. For example, Porsche, the German sports car manufacturing firm, began implementing lean in 1991 to reduce the firm's high cost structure to keep the company competitive in the world market. First, the company reduced layers of management throughout the firm to speed decision making. Next, intensive training was used to teach the lean techniques. Waste was eliminated from the production process by having teams analyze the production process and new quality circles were implemented. The number of suppliers was reduced from 950 to 300 by standardizing parts and dropping low volume options. Product development groups were reorganized into cross-functional teams that were collocated and had representatives from production on the team. The actual results from 1991 to 1995 are very encouraging. Inventories were reduced from 17 to 4.2 days on average. Direct plus indirect labor hours per car were reduced from 120 to 76 hours. Finally, the number of defects of supplied parts was reduced from 10,000 to 1,000 parts per million. (Womack et al., 1996, p.213)

Every firm has a tough start implementing lean manufacturing. Typically, the reason is that only one or two portions of the lean techniques are implemented. Just-in-Time, or JIT, inventory management was a well known "flavor of the month" in the early 1990s. Wiremold is an example of a firm that tried to implement JIT because its V. P. of Operations had seen it during factory tours in Japan.

"He came back praising the concept of Just-in-Time and immediately set about pulling down inventories and reducing lot sizes. What he could not do, because no one knew how, was introduce flow and pull by reducing changeover times for Wiremold's tools and building to a level schedule." (Womack et al., 1996, p. 126)

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2 According to the Material Planning and Logistics manager of the Cleveland Engine Plant, August 1998.
The result of Wiremold's struggles with JIT was that the company slid from record profits to just break even over the following two years. The customer service was considerably lower. Problems that had been covered by the mountains of inventory were now causing disruptions to the schedule. One of their executives noted that the company "nearly JIT'd ourselves to death by doing it the wrong way" (Womack et al., 1996, p. 127). In the end, Wiremold set out to find someone that could help them implement a new way correctly. The significance of this example is that all of the components of lean manufacturing fit together like a puzzle. Each piece is required to make it complete and function properly.

2.4 Summary

Lean production embodies an entirely new set of techniques for manufacturing. Many firms have adopted lean manufacturing in a variety of different ways with varying success. One of the keys to success is implementing the full range of techniques. Simply singling out just one of the techniques, such as JIT, will not necessarily result in success.

The Cologne facility has a long history of as a manufacturing site for Ford. Many of the typical aspects of its mass production heritage can still be seen throughout the site. However, there are many improvement efforts underway to make the assembly operations changeover from mass to lean production techniques.

The problems evident at Cologne are typical throughout the auto industry. There are a number of examples of best practices of lean manufacturing that exist that can be used as models for improving the system. This thesis will step through the process of identifying areas for improvement and the process for implementing those changes to the material handling process at Cologne. The basis for the improvement will be the fundamentals of the Toyota Production System, the inventor of lean manufacturing.
2.4.1 Key Summary Points

- Cologne has a firmly entrenched mass production heritage at the moment that is not different from other traditional established automakers.
- Cologne is in the process of implementing FPS and LLP in areas that will improve its operations.
- Lean methods could help Cologne, primarily with variation reduction and elimination of waste.
- Lean manufacturing must be implemented as a whole since the parts don’t function well independently. (e.g. JIT doesn’t work without a predictable, level schedule)
Chapter 3: Initial Analysis

3.1 Introduction

A large amount of data needed to be collected in order to begin to reconfigure elements of the material flow system. First, packaging data was needed to determine the lineside address and quantities per box. Next, the quantity and variation of parts demanded was required. Finally, an assumption was made regarding delivery time average and variation from the suppliers. All of this data was used as input for determining the optimal inventory levels in the plant, discussed in Chapter 4.

3.2 Data Collection

3.2.1 Lineside Data for Every Part

The first step was to gather detailed descriptions of the assembly line part usage and packaging characteristics. A team of material handling workers was established to record packaging data for each part by walking down the line and writing down the information, shown in Table 1, which was entered into a database for later use.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>Prefix, Base and Suffix of Part Number</td>
</tr>
<tr>
<td>POF</td>
<td>Point of Fit – Lineside Address</td>
</tr>
<tr>
<td>Packaging</td>
<td>Type of Packaging:</td>
</tr>
<tr>
<td></td>
<td>FLC – 1m³ recyclable box</td>
</tr>
<tr>
<td></td>
<td>KLT – one of three sizes of small containers</td>
</tr>
<tr>
<td></td>
<td>Karton – cardboard box</td>
</tr>
<tr>
<td>Quantity</td>
<td>Number of Pieces per Box</td>
</tr>
</tbody>
</table>

Incidentally, there was a packaging database on site, called NewPac, which should have contained all of this information. However, the database was not regularly maintained and the information was not necessarily reliable due to frequent part number revisions and packaging changes. By November
1998, the plant had implemented a new system for production control, named CMMS3. The packaging data from NewPac was updated and linked into this system which should improve the reliability of this information in the future.

3.2.2 Demand Data for Every Part

The next step in the analysis was to determine the usage rate for each part. The Cologne plant maintains its production control information within a database, to which queries were written to determine several attributes, shown in Table 2, related to the production usage of each part. Combinations of this data would be used later to determine the optimal inventory levels within the material flow process.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part number</td>
<td>Prefix, Base and Suffix of Part Number</td>
</tr>
<tr>
<td>Demand</td>
<td>Daily number of parts demanded by the line</td>
</tr>
<tr>
<td>Supplier</td>
<td>Supplier code</td>
</tr>
<tr>
<td>Frequency</td>
<td>Delivery Frequency to the plant, i.e. daily, weekly, monthly, etc.</td>
</tr>
<tr>
<td>Leadtime</td>
<td>Delivery travel time in days from the supplier to Cologne</td>
</tr>
<tr>
<td>Inventory</td>
<td>Quantity of parts in the plant inventory</td>
</tr>
</tbody>
</table>

There were a few inconsistencies in the database, particularly related to Frequency and to Leadtime. The data was not updated on a regular manner for both of these attributes. The primary reason it was not updated was that no calculations were dependent on these numbers and no one had the direct ownership of updating any changes to these attributes. Additionally, there was no code for deliveries more frequent than once per day, even though several suppliers delivered two or three times per day.

New part numbers entered into the system when an engineering change occurred caused another inconsistency in the data. In these case, the inventory balance of obsolete parts was not always updated immediately after the change to the new part occurred, and as a result the information was not readily available for some new parts running on the line.
3.2.3 Travel Time for Every Part

The travel time for each part was taken directly from the Ford production database from the field Leadtime. In most cases, there was not a distribution of actual data to compare this value with. Additionally, there was no information available regarding estimates for non-travel components of an order's leadtime. To simplify the analysis, it was assumed that variation in non-travel leadtime was negligible compared to that of travel time. In order to estimate a variance for the distribution of the leadtime, parts were broken into two distinct classifications - those coming from within Europe and those from outside of Europe.

Parts coming from within Europe typically had leadtimes of less than five days. The most distant European suppliers for Cologne were located in Portugal, which was a five-day drive. However, the plant also had many parts that were within a one-day delivery range. For all parts, with delivery times less than or equal to 5 days, it was assumed that the distribution of leadtimes was normal with a standard deviation, $\sigma$, of 0.5 days. Using this assumption, a 99% confidence interval for truck arrival would be within 1.15 days of the expected arrival time.

The second distribution of leadtimes was for parts coming from outside of Europe. Typically, these parts had longer leadtimes and higher variability associated with the delivery times due to customs and other shipping related issues. For these parts, the distribution was assumed to be normal with a standard deviation of 1 day. Using this assumption, a 99% confidence interval for truck arrival would be within 2.3 days of the expected arrival time.

Each of these distributions was based upon speaking with the personnel from the shipping dock and material control at the Cologne plant. The distinction was made in order to account for the higher variability from parts sourced from outside of Europe. In practice, actual data from the delivery times should be used to set the inventory levels rather than the approximations proposed here. Following the arrival of the new CMMS3 system in November 1998, actual delivery data should be available within the database. This should significantly improve the estimates for order leadtime and variation.
3.3 **Summary**

In order to determine inventory levels, first part demand and order leadtime information was required. The production control database was queried to gather some of this data. However the packaging directly on the line was also used. The integrity of this data is very important, since the smooth flow of the plant depends upon it. In several situations, where the data was questioned, assumptions were made and the progress continued on. As the new production control database comes along, the robustness of the data should improve.

3.3.1 **Key Summary Points**

- Packaging data from the actual lineside packaging was used to determine packaging type and quantity per box.
- The production control database was used to determine daily part demanded by the assembly lines.
- Two assumptions were made for the variance of the travel times from European and non-European suppliers since data was not available for this information.
Chapter 4: Improvements in the Inventory Management Methods

4.1 Introduction

The Cologne plant has been focusing on inventory reduction for several years. The current inventory management policy of the plant was a simple rule set by management, 1.4 days stock on average. Monthly inventory meetings consisting of upper management of the plant and inventory control analysts established the inventory levels. However many problems still arise with either stockouts or too much stock.

Figure 3: Inventory Value and Days Stock, September 1998
Upon analyzing data in September 1998, the average number of days inventory in stock found in the plant based upon the weekly average part usage was found to be 89 Days. The inventory was 25 days based upon maximum usage documented over the month. However, there were a number of parts with a very high number of days that skew the data. The median based on the average demand was 4.0 days and 1.9 days based on maximum demand. Figure 3 contains an example of a report of the excess inventory conditions for parts over 10,000 DM ($6,000) in value and over 10 days stock. This figure identifies parts with highly valued inventory levels that may be able to be reduced. The objective of this chapter is to investigate setting the optimum inventory level by using the Base Stock Model.

4.2 The Inventory Control Process

There were several steps in the inventory control process. The process began with either an Electronic Data Interchange (EDI) with the suppliers or a manual order. The suppliers were given a preliminary planned build schedule 15 days out. The plan was finalized into a firm build schedule, which was fixed five days prior to the build date. The suppliers would ship to this forecasted build volume. The inventory shipped from the supplier was then received at the Cologne plant and put into storage or used immediately at the line.

The first line of inventory control was the Stockchecker. This person was responsible for maintaining inventory counts and for verifying the level of the inventory was adequate to meet the production needs. When I first arrived at the plant, the Stockcheckers were assigned to certain suppliers. However, before I left they were in the process of converting to have the responsibility for a distinct portion of one line.

Typically, the Stockcheckers verified the production requirements by looking at the demand over the next three days and checking this amount versus what was in stock at the moment. This information was available from the production control system and from daily "shortage" or "excess" reports of inventory values.
In cases where the Stockchecker found inventory above the necessary level, they were supposed to notify the Check and Adjust group. This group was responsible for eliminating obsolete parts and for adjusting the level of stock to an appropriate level.

If the inventory level was not enough to meet the next day’s production, then action was taken to expedite the order from the supplier through the Disponent group. The Disponent group was responsible for controlling the logistics traffic to the plant. Typically they controlled the truck movements within the yard and called the trucks into the receiving area when needed. They were normally responsible for coordinating the shipments from several suppliers. The Disponent would know where the needed parts were in the shipment process and if they could be expedited.

Figure 4: Inventory Level Scenario Based on Daily Delivery

The target inventory level of 1.4 days on average was based on the fact that the majority of the parts had daily deliveries. A saw-toothed inventory level as shown in Figure 4 results from the normal daily usage and the daily deliveries. The 1.4 days average stock is a result of the maximum stock level of
1.9 days and the minimum of 0.9 days safety stock, or "Iron Reserve", results in the average of 1.4 days stock goal set by management.

4.3 Problems with the Current System

4.3.1 Stock Control Problems

The inventory control system described above had several systemic problems. First, there were inherently large numbers of parts that were not in stock at any given time. One reason for this was the fact that the Stockcheckers only looked over demand for next three days to check if there were enough parts in stock. This resulted in many cases where there was not enough inventory in the pipeline to meet the demand over the next few days. Additionally, sometimes they would expedite orders from the suppliers, which would cause excess inventory to be shipped.

Some of the problems in the system were a result of differences between the actual count of stock on the floor and the stock found in the computer system. Parts were located in many different areas of the plant and it was difficult for the Stockcheckers to get an actual count of the parts. In some cases, the parts were not entered into the system even though they were on the floor. In other cases, part count data was entered into the system wrong.

Figure 5: Variation Found Within the Supply Chain
4.3.2 Variation in the Supply Chain

There are typically at least two types of variation inherent in a supply chain, demand variation and replenishment leadtime variation from the supplier, as shown in Figure 5. However, in the Cologne inventory control system the optimal inventory level was not based on variation.

To determine the effect of variation, the distribution of demand during the average leadtime is used to determine the variation in demand. Additionally, the distribution of leadtime is a function of the variation in leadtime of any given order is also needed. Typically, the distributions of each of these variables can be approximated by the normal distribution, as indicated in the bell shaped curves in Figure 5, then the historical values are used as estimates for the expected values in the future.

To account for the overall variation in the supply chain, the two distributions of order leadtime and demand will be combined to form the synthesized distribution. While the synthesized distribution is not strictly a normal distribution, it can typically be approximated as one. From the synthesized distribution, the optimal minimum and maximum inventory levels can be inferred.

The effect on inventory levels can be logically obtained. For example, the longer the travel time from the supplier, the higher the inventory holding requirements because of the long adjustment time in the inventory level. Additionally, high demand variation is another reason to hold higher inventory levels to cover the periodic swings in demand. Travel time and demand variation are the key variables to minimize in order to lower inventory levels and make the system more predictable.

4.3.3 Management Problems

An additional problem within the system was that corrective action would require long delays to adjusting the inventory levels. The reason for the delay was that there were several groups that the information passed through in order to adjust the level of inventory. In most cases, the priorities were placed only on meeting the demand for the current schedule and excess inventory situations were not as high of a priority. This problem was particularly prevalent on parts with engineering changes. The
Stockcheckers would wait until they received word from the Engineering group that the change was expected to take place in a part number. Typically, by that time the new parts had already been sent from the supplier. This caused a problem on the floor regarding which part to use and what to do with the old parts. It also caused a problem in bookkeeping because the old parts needed to be purged from the system. Overall there were many significant problems with the change procedures to new part versions.

Another problem resulted from the fact that since inventory control was spread over several groups, no one took ownership for the problem. The Stockcheckers only counted the parts and looked to make sure there was enough to meet the demand. The Check and Adjust group only adjusted levels when requested. The Disponents' focus was only to move the parts in a smooth flow to prevent the line from stopping, not reduction in waste. In summary, the lack of ownership caused inventory reduction efforts to stall.

\textbf{4.4 Reduction in Variation}

The problems mentioned with the system were some of the primary drivers of the variation in the system. In particular, the engineering changes drove a significant amount of variation in the inventory levels on a regular basis. Adequate control systems were not in place for the part number changes. The result was that obsolete parts regularly were not removed from the line and the old and new parts became mixed. Standardizing the control process for new part numbers would greatly improve the changeover to new parts.

Additionally, the demand variation of new parts caused the demand pattern of these parts to look quite irregular. The optimal inventory level is difficult to calculate based on having a demand of zero until the part is released for use and then a demand higher than zero. Historical demand for the old part number could be used as a predictor of what level of inventory to carry for the new part number.

Another difficult part of the system was related to the Daily Call In, or DCI, which was not always a reliable method of control for the suppliers' shipments. DCI was the broadcast of the required
part schedule to the suppliers. This schedule was fixed approximately five days before the parts were
needed. In many cases the suppliers would ship more or less than the DCI request for the given day. It
was truly a push system. For example, when the supplier would have a shutdown, in many cases they
would over ship parts to the plant to cover their shutdown. Then the assembly plant had to find a place for
these extra parts. In one instance during July 1998, the supplier for air cleaners had a shutdown at their
plant. They sent several extra truckloads to the Cologne plant to cover their shutdown. The parts remained
in the marketplace for several months waiting to be used. Meanwhile, other air cleaners were being used
in production on a last-in-first-out basis. An additional problem, related to DCI, was that the schedule
would shift based on process variation in paint, body construction or some other area of the plant.

Another source of variability was that the location of all of the parts in the plant was not standard.
In the air cleaner example, the parts were stored away from the normal receiving point so they were never
used in a FIFO manner because the operators never saw the old parts waiting in the marketplace.
Additionally, the variability in storage location wasted the operators' time looking for the parts. Also, in
some cases the stock quantities were incorrect in the computer system because the parts were not counted
because they could not be found.

Finally, the delays in adjustment time and lack of ownership explained before caused the
problems in the plant to amplify. For example, at one point several days of inventory for a part used for
insulation was found in a very congested area of the plant. Upon notifying the stockcheckers, they
notified the check and adjust group, however, nothing was ever done to adjust the level. After several
attempts of asking about solving the problem, no one would work on reducing the level. The result was
that the additional deliveries would simply begin to pile up because there were other fires to fight.

4.5 The Importance of Packaging

Packaging is another important aspect of the material control process. Throughout the Cologne
plant, large containers full of material can be found. The reason is a result of the packaging conversion
strategy begun in 1997 by the centralized packaging group. This group works with all of the plants in Europe to consistently package the parts in the most cost effective box size. However, in many cases, the most cost effective box size for the packaging group can lead to large boxes of material that sit on the manufacturing floor for days.

The analysis in Figure 6 is a histogram of the number of parts that may have incorrect packaging. The figure shows that 48% of the parts have packaging that holds more than a full daily requirement of the parts. The packaging group should take a look at the packaging for each part to see if the quantity per box could be reduced. The FPS target is to have approximately 2 hours stock on average at the lineside. Based on the analysis shown in Figure 6, the FPS goal would be impossible due to the high number of parts with packaging containing over one day's worth of stock.

Figure 6: The Impact of Packaging and the Time per Box
4.6 Improvements to the Current System

4.6.1 Establishing Ownership

One improvement to the system would be to assign ownership of the inventory levels to one group within the plant. They should be responsible for both maintaining the operational stock and then to systematically reduce the levels lower whenever possible. The Stockchecking group would be well suited for this task. The realignment of the stockcheckers to certain areas of the plant, rather than focused around particular suppliers as was the case in December 1998, is a step in the right direction. Additionally, the group should begin to look at the entire inventory in the pipeline at least five days out, not only the inventory on hand and the next three days demand. The system should all function together and the stockcheckers should work closely with the material handling operators to function as a team.

4.6.2 Using the Base Stock Model for Optimal Inventory Levels

Setting the inventory levels is the most important part of a JIT replenishment system. If too much inventory is specified, all the benefits of JIT are lost. Waste of inventory results and quality problems can be hidden. By setting the inventory levels too low, the system may not meet the requirements of the customer. Basing the inventory levels by accounting for uncertainty in the demand and leadtime can prevent both of these situations.

The Base Stock Model uses the variance of the demand during the leadtime to calculate the minimum, “Min”, and maximum, “Max”, target levels of inventory. It is a well-known model that has been investigated for use by a number of other sources. (Monden, 1989, pp. 423-436; B. Black, 1998, p. 25; Nahmias, 1997, pp. 265-295) This model predicts how much inventory should be held based on the mean and variation of both historical demand and order leadtime. Using basic statistics and the assumption that the distributions are normal, the mean inventory in the pipeline and synthesized standard deviation of the system can be obtained as the following:

Target Inventory = Average Daily Demand Over the Leadtime + Safety Stock

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The equation for the target inventory level in the pipeline can be formulated as:

\[ \bar{I} = \mu_T \cdot \mu_D + SS \]

While the variation of the synthesized distribution of the inventory can be formulated:

\[ \sigma_i^2 = \mu_T \cdot \sigma_D^2 + \mu_D^2 \cdot \sigma_T^2 \]

Where the following variables are used:

- \( I \): Expected number of parts in inventory in the total pipeline
- \( \mu_T \): Mean of non-travel leadtime (t), travel time (l) and working days between deliveries (d) all in days
- \( \mu_D \): Expected average daily demand, \( Q_D \), over \((t + l + d)\) in number of parts
- \( \sigma_i^2 \): Synthesized variance of the inventory level
- \( \sigma_D \): Standard deviation of daily demand in number of parts
- \( \sigma_T \): Standard deviation of non-travel and travel time in days
- \( SS \): Safety Stock, described below

As noted earlier, this particular formulation accounts for variation in both demand and leadtime. The variation in demand was based on the actual data gathered from Cologne production database as described in Chapter 3. The variation in leadtime was determined based on assumptions discussed in Section 3.1.3.

In order to meet the needs of the customer in the next period, the inventory level in the marketplace, \( I \), after demands are placed on it must be greater than or equal to zero. Safety stock is used to meet the variation in demand beyond what is expected. The safety stock can be determined by assuming a probability of always having enough stock on hand, represented as:

\[ \text{Probability} \ (I - q \geq 0) = \alpha \]

Where,

- \( \alpha \): Customer service level desired, assume \( \alpha = 99\% \)
- \( q \): Amount demanded by the customer
- \( I \): Inventory level in the store

By choosing \( \alpha = 99\% \), the safety stock required to meet the demand 99% of the time can be determined.
The first step, in calculating the safety stock, is to determine the service level factor, $Z$, implied by choosing a level of $\alpha$ from the standard normal distribution. By choosing a level of $\alpha = 95\%$ or $\alpha = 99\%$, $Z$ is implied as $Z = 1.64$ or $Z = 2.33$, respectively. Based on the assumption of a service level factor, $\alpha = 99\%$, the safety stock level, $SS$, can be determined by:

$$SS = Z \times \sigma _{ \gamma } = 2.33 \times \sigma _{ \gamma }$$

The term, $Z \times \sigma _{ \gamma }$, represents the safety, or minimum, stock necessary to meet the variation in upcoming demand. Additionally, it represents the initial stock needed in the system to begin the cycle for a new part.

The maximum and minimum levels that should be maintained in the plant at any given time can be calculated from the safety stock and mean demand as the following:

$$\text{Max} = \mu _{D} \times \text{Days between Successive Deliveries} + \text{Safety Stock}, \text{ or}$$

$$\text{Max} = \mu _{D} \times d + Z \times \sigma _{ \gamma }$$

and,

$$\text{Min} = \text{Safety Stock} = Z \times \sigma _{ \gamma }$$

The values calculated for Min and Max represent the optimal inventory levels within the plant. There are many factors that affect these inventory levels. First, more inventory is needed to cover a supplier that is far away due to the long leadtime associated with adjusting the inventory level. Second, the variation in the travel time from the supplier requires the plant to hold inventory in case the supplier is late with the delivery. Third, the variation in part demand makes it more difficult to predict exactly what is needed in the plant on any given day.

Ideally the plant would work using a pull system, and only replace the inventory that is used from the Max value each day. Theoretically, that is how the plant operates today using the DCI. However, the long leadtime from the suppliers and high variation in both the demand and travel time make it difficult for suppliers to adjust the levels quickly.
4.7 Evaluation of the New Methods Within the Cologne Plant

4.7.1 Evaluating the Cologne Plant Inventory Levels Using the Base Stock Model

By using the Base Stock Model to calculate the optimal Min and Max inventory levels, the result is that some parts are over the optimal level and some parts are under the optimal level. The graph in Figure 7 shows the difference between the actual stock shown in the production control database versus the optimal inventory level predicted by the Base Stock Model with a service level of 99%. The necessary adjustment to achieve the optimal inventory value is represented by the height of the column. The height is the amount of inventory beyond the requirement calculated using the base stock model. The graph shows this adjustment in inventory measured in day's stock based on the average daily usage. Where the height of the column is below zero, the plant should invest in more inventory to cover the variation on these parts. Where the height of the column is above zero, the plant could reduce the inventory level by this amount of days for these parts and still meet the demands of production with a 99% confidence level.

Figure 7: Difference between Actual and Optimal Inventory Levels from the Base Stock Model

The result to the plant from implementing the Base Stock Model would be significant in dollar terms. Using the available data for 1550 parts of 2537 parts with demand on November 20 1998, the model predicts that the total inventory level in the plant should be 15.2 million DM (approx. $9.1
million). The total inventory held in the plant for these particular part numbers was 17.2 million DM (approx. $10.3 million). The summary of the savings to the plant can be calculated as shown in Table 3. A one time savings of 2.0 million DM ($1.2 million) and an ongoing savings of 320,000 DM ($190,000) per year.

Table 3: Projected Inventory Savings Based on Implementing the Base Stock Model for Inventory Control (using a 99% Service level)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value, in thousands</th>
<th>Percentage of Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory Value, Nov. 20, 1998</td>
<td>17,155 DM</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>$10,293</td>
<td></td>
</tr>
<tr>
<td>Optimal Inventory Value, calculated using the Base Stock Model</td>
<td>15,171 DM</td>
<td>88%</td>
</tr>
<tr>
<td></td>
<td>$9,103</td>
<td></td>
</tr>
<tr>
<td>One Time Savings from Inventory Liquidation</td>
<td>1,984 DM</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>$1,190</td>
<td></td>
</tr>
<tr>
<td>Annual Savings from Reduction in Working Capital</td>
<td>317 DM</td>
<td>N/A</td>
</tr>
<tr>
<td>(valued at 16% Cost of Capital)</td>
<td>$190</td>
<td></td>
</tr>
</tbody>
</table>

### 4.7.2 Practical Usage of the Base Stock Model

At the conclusion of this research in December 1998, the Cologne plant was not using the Base Stock Model for inventory control. However, this model could be easily implemented into the current management process at the Cologne plant. In particular the new procedure could be integrated into the new CMMS3 production control software installed during November 1998. The CMMS3 system will centralize all of the production and logistics information for the entire plant. It could effectively be expanded as a tool for better inventory control as well.

Integration would not be difficult because the CMMS system has a database that contains information on the daily demand of each part and the historical leadtime from the suppliers. From this table of data, the average and standard deviation for travel time and demand could be calculated. The
program could use this information to calculate, using the Base Stock Model, the optimum minimum and maximum stock levels of inventory to hold in the plant.

The result would be a better target for the inventory level necessary to meet the needs of the assembly line. Additionally, the inventory requirements would be more long range focused than the 3 day window that is currently used at the moment. High and low levels of inventory could be monitored through regular reports, similar to what is now used by the Stockcheckers for inventory control. Overall, the process should result in better serving the needs of the final customer, the assembly line, and in saving money with lower inventory investments.

4.7.3 Comparison of the Base Stock Model to FPS

FPS presents a third technique to setting inventory levels, the others being the Base Stock Model and management policy of 1.4 days. The Base Stock Model is significantly different from the FPS approach to calculate optimal inventory levels. The FPS technique was evaluated from the training materials for the SMF Single Point Lessons published by the Ford FPS central office in Dearborn. This analysis will present why the Base Stock Model is more appropriate than the FPS approach.

The Base Stock Model is a theoretical method to calculate the optimal inventory levels in a plant based on demand and leadtime variation. In contrast, the FPS approach does not take into account variation when setting the inventory levels for Min and Max. It simply uses a safety factor of 0.5 times the expected demand over the replenishment time. The safety stock calculated using the FPS rules is:

\[ \text{Safety Stock}_{FPS} = 0.5 \times \mu_D \]

Comparing the Base Stock Model with the FPS system results in an interesting observation. The FPS numbers imply a coefficient of variance of 0.2, assuming a 99% service level or 0.3 assuming a 95% service level. This result is obtained by the following manner:

\[ \text{Max}_{FPS} = \mu_D + 0.5 \times \mu_D \]
Assuming a normal distribution of the demand during the leadtime and $Z$ equal to the standard normal distribution coefficient, the following relationship is true:

$$\text{Max}_{\text{Base Stock}} = \mu_D + Z \cdot \sigma_I$$

Setting the two equations for max stock equal results in:

$$\mu_D + Z \cdot \sigma_I = \mu_D + 0.5 \cdot \mu_D$$

From which the coefficient of variation can be calculated after simplifying the above equation:

$$\text{Coefficient of Variation} = \frac{\mu_D}{\sigma_I} = 0.5 / Z = 0.5 / 2.33 = 0.2$$

Based on the data collected for this thesis, the minimum coefficient of variation for all parts was greater than 0.2, as shown in Figure 8. This implies that using the FPS numbers for calculating the inventory levels will result in too little inventory in most cases. At the moment, the FPS system has only been applied to internal material flow routes, however there are serious problems that could result from using such a simplified calculation to set optimal inventory levels from the incoming supply chain.

Figure 8: Coefficient of Variation of Parts
4.8 Summary

The inventory control policies followed by the Cologne plant at the moment are having problems meeting the needs of the plant. There are parts shortages, excess inventory and changeover problems related to new part models.

This chapter proposed several methods to fixing these problems. First, changing the management structure for inventory control and adopting one group dedicated to inventory control within the supply chain. Second, establishing optimal inventory levels, using the Base Stock Model, based on historical demand and replenishment time average and standard deviation to account for variation within the supply chain.

The result of these efforts would be that the customer will be served better and that the group can begin to focus on improvement activities on variation reduction to support inventory reduction efforts. The calculations show that the plant can theoretically achieve a reduction in overall inventory level of approximately 12%. The result would be a one-time savings of about $1.2 million in inventory reduction and an annual savings of approximately $190,000 per year due to the reduction in working capital required.

4.8.1 Key Summary Points

- The packaging, with almost 50% of boxes containing at least 1 day's stock in a box, is not consistent with FPS guidelines for approximately 2 hour stock at the lineside.
- Inventory control is primarily based only on chasing shortage parts at the moment resulting from 3 day view of demand for control and adjustment purposes.
- Management goal of 1.4 days stock on average is not realistic given the current high variation in the demand and leadtime.
- The Base Stock Model could be used to integrate variation into the inventory control methods for the supply chain. Overall savings by using the Base Stock Model are estimated at $190,000 per year plus a one time savings of $1,200,000.
- Unlike the Base Stock Model, FPS's approach to inventory levels does not explicitly take variation into account, in most cases resulting in inventory levels that are too low.
- High coefficient of variation for a large number of parts implies a large amount of inventory investment necessary for these parts.
Chapter 5: Improvements in the Material Receipt and Storage Process

5.1 Introduction

This chapter will discuss the current methods of receiving material into the plant and storing it temporarily until it is needed at the line. A method for eliminating waste from the material receipt process is presented. Additionally, methods used to organize the material storage process are presented.

5.2 Current Material Receipt and Storage Process

The current material handling process utilizes equipment typically expected for a mass production plant, forklifts, tow motors, and large wagons. The process is designed to facilitate using large boxes that hold several hours, or days, of material. A more detailed description of the material receipt process will be given below, however a summary is contained in Figure 9.

Figure 9: Summary of Receiving Material Flow Process

The process begins at the receiving dock, where the large 40-foot trucks are unloaded. The plant as a whole receives about 160 trucks per day. Over half of that volume, between 85-90 trucks, is received at the largest receiving area, 2 - Y South, as shown in Table 4. These trucks are called in with the material as needed from a temporary waiting area. The trucks are completely unloaded in the receiving area and the boxes are placed on the floor. Approximately 5 trucks are unloaded at one time.
Table 4: Average Truck Deliveries to Cologne Assembly, Hall Y.

<table>
<thead>
<tr>
<th>Date</th>
<th>Total Trucks</th>
<th>2 Y-South</th>
<th>3 Y-East</th>
<th>5 Y-North</th>
<th>6 FK Hall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average 19-30 Oct 98</td>
<td>158.9</td>
<td>87.4</td>
<td>33</td>
<td>6.1</td>
<td>32.4</td>
</tr>
</tbody>
</table>

Data from Wolfgang Sunkel 6. Nov 98

After the material is placed on the floor, the Prüfer, or checker, verifies the quantity on the shipment matches the quantity on the bill of lading. The checker also writes an address and the date on the box label, which denotes the delivery location.

The material has two possible destinations from the receiving area: direct to the lineside or to the marketplace. Delivering material direct to the lineside was the primary flow for large material with low packaging density and/or large, high usage special racks, such as instrument panels, carpets, etc. The wagons of this type of material were circulated on a fairly regular basis with a delivery cycle time between 30 to 60 minutes. There was a dedicated driver for this material. Other material that was delivered directly to the line was material that was running in short supply at the line.

The second delivery option for the material was to the marketplace, which was the method used for the majority of the material. The marketplace was developed as a temporary holding area for material. In many cases there was not enough room at the lineside to store all of the material in the plant. The marketplace served as a temporary buffer for this volume of material. It was located in the vicinity of the receiving area on the path between the receiving dock and the assembly lines. The assembly line point of fit determined the aisle for the material in the marketplace. One marketplace aisle was designated for each of the assembly lines. The material for each of the lines was stored in its specified marketplace. One forklift driver unloaded the wagons, put the material in the temporary storage location and maintained control of the marketplace. When the material was needed, this same driver would pull the material out and put it on a wagon for delivery.
5.3 Problems with the Current Process

5.3.1 Waste of Waiting

The material receipt process had several different types of waste that were evident. The most prevalent waste in the current process was waiting. The parts would wait in the trucks outside the plant for several hours. Next, the parts would wait on the floor of the receiving dock for up to a shift, after being unloaded from the truck, waiting to be loaded on wagons for delivery. Finally, the parts would wait still longer, while on the wagons, at the final destination to be unloaded.

One of the primary reasons for the waiting was the lack of information flow between the parts that were needed at the line and the material drivers. The drivers simply drove the parts that they thought the line needed or in some cases took whatever trailer they felt like.

Another reason for waiting was the fact that, as the material was stacked in the receiving dock, it was grouped in an area according to which truck it came in on. The trucks had mixed loads in most cases, so some of the material on the truck was needed more urgently. The other material simply sat on the dock until needed or until someone had time to put it away.

An third source of waiting in the current system was due to the manual checks and labeling that were needed on the invoice from the truck. This manual operation caused an extra step in the unloading process and the material had to wait while it was checked. The forklift driver that unloaded the truck had to put the box down for verification, which led to unloading the whole truck as quickly as possible and then leaving the material in an area until it could be checked. A better way would be to have the unloading forklift check the invoice and then place the material in a more proper location based on need.

5.3.2 Waste of Production Resources

A second large problem in the system was the waste of production resources that resulted from the lack of standardized working procedures for the normal material delivery. In most cases trains full of the same type of material were delivered to the lines at once without mixing the loads. This caused a
problem at the lineside of where to store the material, since the deliveries were not level with the usage rates in most cases. Typically this was resolved with a number of unnecessary material moves. Additionally, the deliveries were typically not based on any type of pull signal from the line. It was a push system, resulting in higher inventory levels and congestion at the lines that inevitably caused extra work.

Another problem resulting from the lack of standard work within the current system was the lack of First-In-First-Out, or FIFO, usage of material. The material that came into the receiving dock, in many cases, may go directly to the line, while older material waited in the marketplace, resulting in a last-in-first-out usage pattern for the material. Realigning the linefeeding material flow process as described in Chapter 6 could help this problem significantly. The result of not using FIFO was that material defects could exist in the older material and would not be easily found.

A third component of the wasted production resources resulted from the distance that the linefeeders had to travel from the receiving dock to the assembly lines. As stated before, over 50% of the material was delivered to the south dock. This dock was located about 500 meters from the assembly lines. There were several other docks that could be used that were less than 100 meters from the assembly lines. The extra 400 meter material transport is a waste of the production resources.

5.3.3 Waste of Inventory

A third significant waste that emerged from the system was inventory. One of the biggest sources of this waste was the push system for the material from the suppliers and material handlers. The perception of what stock was needed, not a pull system, determined what material the material handler generally delivered to the line. As for the marketplace, whatever was delivered from the suppliers, it was shoved in the marketplace for later use.

Additionally, the inventory levels were not really controlled. The only material to be worried about was shortage parts needed for production. The material handlers did not work closely with a
stockchecker to ensure that material stock levels did not exceed any maximum. The "just-in-case" method of inventory management was generally followed.

The process was also not very visual in terms of inventory control. The maximum and minimum material usage levels were not posted. Additionally, the parts were not found in standard locations. The system was thought to be more "flexible" without these designations by the operators.

5.4 Improvements to the Current System

5.4.1 Improvements to Receiving

The receiving process was not a significant focus area of this research, however there are a few items that were experimented with during the course of the research. As a result there are only a few recommendations for improvement to the system that were not implemented during the project.

First, the use of the south dock for over 50% of the material delivery is a significant waste of manpower to deliver the material to the assembly lines in the eastern part of the plant. Several parts were identified to move the receiving area from the south to the east dock during the project. The parts identified were shock absorbers, springs, window glass, roof material, carpets and floor insulation. In total, this amounted to 5 trucks per day that would be received at the east dock. The movement of these parts would result in savings of at least one operator for a shift, due to a reduction in transport distance. An additional result is that the system would be more responsive to the needs of the line since the parts would be significantly closer. The only negative noted in the system was that there would be an estimated 15% increase in work for the operators at the east receiving dock.

A second area for improvement in the receiving process would be to have the lineside location printed on the part labels on each box of material. In this manner the forklift drivers could sort the material as needed at unloading. The forklift driver could scan the barcode on the box to verify the material contents as well. This would allow the material to flow through the process with fewer "touches" and less delay. Additionally, the labels could be positioned better on the box. Currently, the label is only
found on two sides of the box. By using more stickers as labels, all four sides of the box could be marked which would help the material handlers.

A third area of improvement would be to divide the material in the dock into regular areas by destination. For example, there would be an area designated Trim 1 that would contain all of the parts for that particular line. The forklift driver, upon taking the parts from the truck, could then move the parts to that particular area of the receiving dock. The material could then be taken on a FIFO basis as needed to the line or marketplace.

The final suggestion would be to implement timed routes to the assembly line. This concept will be developed in more detail in Chapter 6. However, the basic concept is that the drivers know the parts that they need and when they need to deliver them to the line. They could make a regular schedule that could be assisted by a Heijunka box to help meet the needs of the line that they work with. The operators were working with a list-based system in December 1998. This system did create a type of pull system, however the routes were not timed and the delivery process was typically not level with the production need.

5.4.2 Improvements to the Storage Process - The Marketplace

The primary means to improve the storage process at Cologne investigated during this research was that of marketplace implementation. A marketplace is a temporary storage area with one specifically defined storage location for each part. It is used as a holding buffer between the time that the parts are delivered from the supplier until when the line needs the parts, since in most cases there was not enough room at the lineside.

5.4.3 Why use a Marketplace?

In theory, the parts in the marketplace exhibit the waste of waiting. Material movements into the marketplaces are non-value added. The most efficient method would be to have the supplier deliver
directly to the point of fit at the line, eliminating the need for the marketplace. The marketplace detracts from quality since parts are allowed to sit, and quality problems may be hidden within them.

However, in certain cases, the marketplace is helpful to buffer the variation in both the customer (assembly line) demand and the variation in delivery from the supplier. Typically, buffers are not associated with lean manufacturing, however, even Toyota Georgetown had marketplaces for parts. At Toyota, parts found in the marketplace were long leadtime parts from Japan or other far away suppliers. An additional reason for a marketplace is that the shipping cost may be too great to justify the additional cost of shipping small lots.

Based on its study of TPS, the FPS group recommended installing marketplaces with tightly controlled inventory levels for the minimum and maximum value of the stock. Marketplaces are a necessity when trying to covert a typical mass production plant over to lean production. The marketplace is a buffer that helps organize, sort, and sift parts. Without the marketplace in a brownfield site, conversion would not be possible because you first need to organize the parts before you can reduce the inventory level. The purpose of the marketplace is to provide a "corralled" area to confine and organize the parts. Then the inventory level of the parts can be systematically reduced.

5.4.4 Two Types of Marketplaces - Call versus Card

There are two types of marketplaces resulting from two distinct part types used by FPS, Call and Card parts. Call parts are parts that require a forklift or some other assist to move from shipping to the point of fit. Card parts are parts that fit in boxes and that can be delivered by hand. These two types of parts require different marketplace systems.

Call parts typically come in large boxes or special racks, such as the FLC that was shown in Figure 2. FPS designates that no more than 20% of the parts should be call parts. The reason for this is that call parts require specialized equipment in a number of ways. First, typically special racks or boxes
must be designed for the large parts. Next, expensive forklifts must be purchased requiring many wasted moves to deliver the parts to the line.

However the largest problem with the call parts is that a large investment is required in the infrastructure of a call system. The call system is typically a button that would be pushed by the operator at the line notifying the forklift driver that a part is needed. The forklift driver would then drive to the line and deliver the part. During research for this project, several call systems were seen. In Ford's Cleveland Engine Plant, the $500 million call system was removed because it was too inflexible when parts moved positions on the line (they currently use a call system based on a radio call). At Ford's Saarlouis assembly plant, almost all the parts were call parts, and the drivers frantically raced around the plant to meet the calls. However, the infrastructure installed at Saarlouis worked well. Toyota Georgetown also had a few call parts with a similar infrastructure to that of Saarlouis. In summary, for a call part system to work well, the ratio of call parts to card parts in the total system should be low. An example of a well-structured call system is shown in Figure 10, a simplified diagram of Toyota's Georgetown plant. In the Figure, the dashed lines indicate the information flow and the solid lines the material flow within the plant.

Figure 10: Material Flow for Call Parts at Toyota Georgetown
Call parts require special marketplaces that work best with floor type storage, where boxes or racks can be slid by the forklifts pushing them from the back to the front of the lines as shown in Figure 11. Each line can be accessed from either end with defined in and out routes, thereby ensuring FIFO material flow. In this type of marketplace, boxes are typically stacked vertically to reduce the area required for storage. Additionally, at Georgetown and Cleveland, the boxes were color coded for better visual management.

**Figure 11:** First In First Out Material Flow in the Call Marketplace Lines

Card parts are the second part type identified by FPS. They are parts that typically come in small KLT boxes that were shown in Figure 2. The card delivery process is normally by hand as an operator drives around the plant on a regular route, similar to the old-fashioned milkman as shown in Figure 12. Along the route, kanban cards are collected which "pull" the material for the next delivery route. In the Figure, the information flow and actual path of the card, is indicated by the dashed arrow. The part delivery and actual kanban route is indicated by the solid arrows. An advantage of the card routes is that they allow flexibility to be built into the system, by involving employees in the process. Additionally, they are easier to control the inventory level. Cleveland engine estimated that the new card-based replenishment system that cost $50,000 to implement has saved $500,000.
One significant problem with card parts is that the shipping density of the parts is reduced. Therefore, the shipping costs may increase. Additionally, most packaging currently comes in large boxes, that must be changed to adapt to the card system. One problem with the conversions, according to the Ford European Packaging Group, is that suppliers normally want to renegotiate the piece price when changing packaging. Additionally, it takes time to convert to the small packaging.

The card part marketplace typically contains a large number of roll-through racks where boxes are pulled from the front of the rack and replenished from the rear as shown in Figure 13. Each rack holds a various number of parts, however each part location is clearly identified and the minimum and maximum number of boxes allowed is clearly visible. The best practice is typically to have the empty boxes return down a lower track so that the boxes will be located at an optimal ergonomic level for the line operator. Additionally, a slide was seen on the racks at Georgetown that allowed the kanban card to slide from the assembly line’s side of the rack by the line to the aisle by gravity, thus eliminating the need to hand the card over to the material handler in the aisle.
For both call and card parts, kanban cards are used to determine the total number of boxes, and therefore inventory, in the system at any time. Additionally, discipline is necessary for both types of marketplaces to function properly. Throughout the marketplace, part labels for each part, as shown in Figure 14, must be maintained. Also, parts cannot have mixed locations and inventory levels must be respected and monitored. Problems must be quickly identified, their root cause determined and a solution implemented to keep the process working smoothly. Additionally, a key component of a successful marketplace strategy is that the inventory level is continually reduced to push the system to lower the level.
5.4.5 **Marketplace Development and Implementation**

The predominant storage area that was being implemented during this research at Cologne was the call marketplace. The primary reason for this was that the packaging at the Cologne plant was typically very large. Additionally, there were extra no drivers available to implement a card based route during the majority of the course of this research.

The marketplace implementation process began in June 1998, when several marketplaces were established within a vacant section of the plant. Their purpose was to act as temporary storage sites for the material until the line needed it. In fact, several empty production lines were used to store material. The idea was that material would be stored in a regular, defined location with visual indicators of the minimum and maximum inventory level.

In the beginning, the marketplace was developed to mirror the assembly line. Each aisle in the marketplace was matched to an aisle in the assembly lines. The first try at implementing a marketplace left a great deal to be desired. Ideally, the parts would have only been found in one location within the marketplace that was designated by a sign. In reality, the parts were stored in the lines somewhat haphazardly. Typically, all of the parts with the same basic part number were grouped together. For example, all door locks were stored together, however the particular types of door locks (i.e. electric, manual) were mixed. It was expected that the operators would pull material from the front of the lines in a FIFO manner and replenishment would be made in the rear as shown in Figure 11. Unfortunately, in the beginning, FIFO was not regularly used because the storage lines only had access from one side, so older parts may remain in the back while newer parts are pulled from the front.

An improvement to the first marketplace design was made with some success. The parts that were stored in lines with access from each end. The boxes could be pushed in from the back and pulled out from the front. Additionally, signs similar to that shown in Figure 14 were clearly hung above each part with the part number and minimum and maximum inventory level. The min and max allowed everyone to easily verify the appropriate inventory level at any time. The min and max were calculated based on the
methodology presented in Chapter 4. Additionally, the signs helped to organize the material location for the operators. When a delivery was necessary to the line, it was easy to identify where the material was stored. The operators commented on several occasions about the advantage of the more visual process.

One problem found within the new marketplace concept was that there must be enough storage locations for each part. In practice, that was very difficult because the excess parts that the plant had on any given day would vary. The result was that on some days parts would overflow the maximum allotted space into other areas. The solution for this should be disciplined application of the "5 Whys" (Womack et al., 1991, p. 152) process of root cause identification and effectively implementing a solution to reduce the variation found in the inventory level.

An additional problem resulted from the introduction of a new part number or a part number change. Typically the new parts were delivered early to the plant where they became mixed in with the normal production parts. There was not a standard procedure that was always followed for this situation, so the result was a mixture and sometimes the cars had to be reworked off the line.

5.5 Summary

The material receipt and storage process was haphazard at the beginning of this research at Cologne. There were many sources of waste and inefficiencies in the process. This research has only touched on a few of the areas in the material receipt and storage process that could be improved through more attention to detail and focusing on implementing standard processes.

The advantages that the operators gained by using the marketplace concepts were noted on several occasions. Operators commented positively about how the organization of the parts helped them find parts easier.

Implementation of these new ideas within the receiving area was not so successful. This was mainly due to the fact that no one was willing to take a risk on such a mission critical area of the plant.
with a new system. Additionally, manpower problems caused many of the new initiatives to be taken slowly. For example, it was difficult to move some parts to another dock due to manpower concerns.

In summary, this research has generated some alternatives that the plant could use to identify and eradicate sources of waste in the receiving and storage areas. Hopefully, in the future, the plant will capitalize on more of these opportunities. Based upon a visit in April 1999, the plant has already begun to do so by implementing new call marketplaces closer to the line for some parts. Additionally, the receiving area is now tightly controlling time windows for supplier deliveries for some suppliers. Progress is definitely going in the right direction.

5.5.1 Key Summary Points

- Approximately 80% of the packaging required large material handling devices for movement at Cologne as opposed to the FPS target of only 20% of part numbers with large packaging that requires forklifts.
- Waiting is the primary source of waste within the material receipt system as parts wait to be delivered.
- Changing part numbers, such as with an engineering change, is difficult to accomplish in the current system and old parts are mixed with new parts.
- Long delivery paths to the point of fit could be shortened through the use of additional receiving docks, such as the one available by Rhein River side of the plant.
- Call parts are large parts or boxes delivered with a forklift. They typically require significant investments in infrastructure for the material handler notification, or “call”, however they used inexpensive floor space.
- Card parts are smaller boxes that can be delivered by hand. They require some investment in roll through racks for the marketplace. Additionally, the most value is obtained by using these parts in conjunction with a card-based pull replenishment system.
- A marketplace is useful to organize the material, ensure material use in a FIFO manner and aid in the control the level of inventory.
- Marketplaces can cause problems when variation causes deliveries into or production pull from them to exceed the maximum stock levels by large amounts. To alleviate this problem, root cause problem solving must be effectively implemented. Additionally, a quarantine area should be developed for overstocked parts.
Chapter 6: Improvements in the Linefeeding Process

6.1 Introduction

The linefeeding process is closely related to the material receipt process described in Chapter 5. This discussion will focus on the material delivery to the lineside from either the marketplace or the receiving area. Additionally, it will cover the removal of the empty containers from the lines. The chapter proposes a new method of operator alignment to improve the delivery process for the customer.

6.2 Current Linefeeding Methods

The typical method for linefeeding in the Cologne plant was to use a tow motor that could pull 3 wagons behind it loaded with material. A forklift driver, either in the marketplace or in the receiving area, loaded the wagon train before the delivery. On the other end, at the lineside, a dedicated forklift driver for the particular assembly line unloaded the train after the driver left it. Another set of drivers pulled the trainloads of empty boxes and trash away. The system had dedicated drivers that worked only on specific routes. The specific routes are shown in Figure 15. The duties of the drivers were separated according to the specific area in which they worked - receiving, recycled containers, trash or marketplace.

Figure 15: Current Cologne Trim Linefeeding Driver Alignment

[Diagram showing driver alignment and routes]

West Marketplace

2 Marketplace Drivers

South Receiving Area

1 Critical Part Driver

4 Direct Receiving Drivers

East Trim Lines

OC

OD/TOD

HOD/TOD

OE

OF/OG

OH

1 Paper Driver

1 Recyclable Container Driver

Total 9 Drivers
The drivers typically took the parts to the line that were available or that were specifically needed. There was an improvement to this system that was sometimes used by the marketplace drivers. The improvement was to use a list at the beginning of the shift to document all the parts that were needed. The driver would then bring those parts on the list as necessary during the shift. The one drawback to this system was that the drivers typically took full trainloads of the same part. The typical result was that a full shift of parts was taken to the line on each trip. However, the supervisors were aware of the possibilities of leveling this system and it was a step in the right direction.

6.3 Problems with the Current System

There were several problems that resulted from the current system. First, the fact that the drivers were dedicated to a specific function was a tremendous influence in their work methods. All of the incentive was related to what they were judged on - their own work area's performance. The receiving area workers tried to clear the receiving area as fast as possible by pushing the material into the assembly lines or marketplaces, resulting in wagon loads of material sitting in the aisles.

Another problem with the alignment of the drivers was that there was a lack of ownership by the drivers of each line. When a problem arose, in many cases the drivers would not take ownership for it. Not because they didn't want to, but because they were not around to hear about the problem. This was particularly true for the drivers from the receiving dock. The drivers from the marketplace were a bit more responsive because they worked within the same group as the forklift drivers at the lineside. The primary reason for this was a lack of communication between the forklift and tow motor drivers.

One of the typical problems that arose were excess parts were delivered to the line while critical parts that were needed were not delivered. Another problem was that wagon loads of material containing boxes for two different aisles and several trainloads of trash and empty boxes which impeded the flow of other material to the lines. Normally the wagons were loaded with all of one type of part. For example, 12 FLC boxes of air cleaner boxes would be on one train. This was not level with the demand from the line.
6.4 Reduction of Variation

Variation was one of the largest influences in the job of the linefeeders. Variation causes the demand for particular parts to be unpredictable, which resulted in problems bringing the right part in the right quantity at the right time. Additionally, it caused problems with storing parts in the marketplaces, on the lineside or in the receiving area.

6.4.1 Line Variation

The largest source of variation in the plant was the fact that the models on the line were not in a predictable mix. Only minimal leveling of the models occurs due to the capacity constraints of the lines. Colors and option packages were not typically leveled and the result was that the linefeeders were not able to predict what parts they should bring next. In a lean environment, the operators would not need to predict what to bring, but would replace what was pulled. At the moment, this communication channel did not exist, so the workers relied solely on their intuition for prediction.

There were many reasons for the variation in the models going down the line. One of the primary reasons was "batch painting". This was the term used for painting all of the cars in regular batches to minimize changeover time between models. The result was that cars of the same color would travel down the line at the same time. The site also had an Automatic Sequencing and Retrieval System, ASRS, that would attempt to match the sequence of cars coming out of paint with the predicted sequence for assembly.

6.4.2 Packaging

The packaging also led to the variation in the demands on the drivers. As stated before, the packaging was not standardized around a certain amount of time per box. The result was that the driver did not know when the box needed to be replaced. In Toyota's factory, the material handler has a route of a specified time. The boxes were sized based on the length of the route. The result was less waste within
the system. In the Cologne plant, the size of the box was based on the standard size that would fit in the truck for minimum shipping cost or based on the size of the part's previous cardboard packaging.

The packaging also caused the additional problem that it required many forklifts to move the material. This resulted in reduced flexibility with the handling of the boxes. In contrast, Toyota has changed most of its parts over to small boxes that can be delivered by hand. This changeover results in increased amounts of flexibility to meet the changing needs of the line with the material flow and lineside space required.

6.4.3 Storage Problems

One of the most visible problems caused by variation was the fact that material would build up in the lines, marketplaces or receiving area. The predictions that the drivers made about material usage by the line resulted in wasted material. Normally this excess material would back up in the aisles on trailers waiting to be unloaded. The forklift drivers would have to waste moves to get around this extra material to find the parts that were actually needed. The lack of standardized storage locations was one cause of the excess material problems, however the other cause was the variation of the line.

6.5 Improvements to the Current System

The management of the current system was a complex web of people and work groups. A simple improvement to the current system was proposed by one of the material handling supervisors. The solution involved simply realigning the wagon train drivers to a particular line and eliminating the functional division of labor.

The way the new system worked is displayed in Figure 16. Each driver was reassigned to one particular aisle to serve in the assembly line. The driver was responsible for driving the wagons of material from the marketplace or receiving area to the lineside, removing the trash wagons and returning the recyclable containers to the receiving area. The reorganization process freed one operator to focus on new work methods for small part delivery using kanban cards.
Figure 16: Realignment of Linefeeding Drivers for the Cologne Trim Lines

Benefits from this system were very obvious during the functional test performed on one assembly line. Teamwork between the driver and forklift operator for each assembly line was enhanced. This eliminated a large portion of the expediting work for the critical part driver and allowed them to focus on other improvement opportunities. Additionally, the assembly line was better served because they knew who was responsible for the material that they needed. The aisles were also kept clear of the excess wagon trains that had collected previously.

Based upon a visit to the Cologne plant in April 1999, the new process is currently in place and working well. The aisles were clear from trailers and the critical part expeditor's work is less. In addition, the material drivers are all currently under the linefeeding supervisor for the trim lines. This helped to realign the drivers' interests to serving the line rather than simply keeping their own area running smoothly.

6.6 Summary

At the beginning of the project, the material linefeeding process at Cologne did not exemplify any of the traits of lean manufacturing. There was no standardized work in the processes, waiting throughout
the system, excessive transport and wasted motion. In the end, a process was developed that would level the load on the drivers and provide better service to the assembly line. The process reorganized the work of the linefeeding driver around serving one assembly line rather than a functional organization. In the end a test route was developed and successfully implemented, and continues to run as of April 1999.

6.6.1 Key Summary Points

- The linefeeding system, arranged by job function, caused problems with waste of waiting, overproduction, and production resources.
- Within the current arrangement, expediters are required to ensure that the customer gets what is needed.
- Alignment of the drivers by aisle will make them more responsive to customer demand and eliminate large amounts of waste, while at the same time keeping the plant more organized and clean.
- Variation is a cause of large problems within the linefeeding process at the moment resulting from many sources.
Chapter 7: Organizational Culture and Change

7.1 Introduction

As previously stated, the Cologne site began production under Henry Ford in the 1930s. Mass production methods have become very deeply engrained in the plant and new methods are not accepted easily. Improvements were accomplished by encouraging the workers to try new ideas and to work independently to implement new methods. However, some other issues, such as work culture and lack of communication, stood in the way of some of the implementation. This chapter also presents a few learning points that I gained from performing this research.

7.2 The Culture of the Work Environment

The many years of traditional mass production at Cologne have made new methods hard to accept. In many cases, inventory in the plant is viewed as part of doing business. The extra box of inventory was "just in case" they ran out, and was not viewed as waste. In fact, workers preferred to have inventory on hand, that way the management did not yell at them for being the source of a line stoppage. This outlook was very difficult to overcome when implementing new systems.

7.2.1 Management Style

The management style in the plant remains very traditional and hierarchical. There was a tremendous rift between workers and management driven primarily by the union. The workers were not typically involved in daily decisions, but simply told what to do and how to do it in many cases. The management style results in a traditional "pass the buck" mentality since in many cases workers were not trusted to make decisions and typically were not rewarded for taking initiative.

Additionally, the involvement of workers in the process was made worse as a result of racial tensions within the plant. In many cases, the plant workers were not German. Typically, workers were immigrants from Italy or Turkey that have come to Germany in search of high wage jobs. In some cases
that I saw, the workers could not even speak German. This makes worker involvement extremely difficult.

7.2.2 Culture of the German Workforce

The German workforce has many strengths, two of which are its creativity and high technical skill. This combination leads to very unique problem solutions. The new ideas created working together with the people during this research added significant value to the firm. However, in several situations a significant emphasis was placed on implementing an overly technical solution to the problem. Care must be taken to keep the solutions simple and "right sized" for the process. Additionally, the creative nature and the historical "craft" nature of the German production works against standardized work. There was an emphasis on each group doing it their own way rather than standardizing on the one method and then improving upon that. Implementing new methods was difficult because they would typically be customized.

Additionally, there are several cultural factors within the German working environment that makes it more difficult to apply new ideas in practice. One particular challenge is communication. German industry is very hierarchical. Working groups are typically very narrowly focused and decisions tend to go up the ladder and then back down through the chain of command. This is not very conducive to group decision making. The problem is compounded by the vastness of the assembly operations. Proposed changes may affect many different groups and all must approve the changes. Womack suggests restructuring the teams of the typical German company to "be focussed horizontally on a linked set of activities along the value stream and perform many of the indirect tasks associated with managing their work, including quality assurance, machine maintenance, tool changes, development of standard work and continuous improvement." (Womack et al., 1996, p. 215)
7.2.3 Other Issues

One of the biggest problems encountered was the high absenteeism within the workforce. Approximately 20% of the workers were out on average. In several cases that I noted, over a 3 year time period several workers were absent in each of those years more than 60 days per year on medical release. This absence was in addition to the standard 12 weeks of vacation for each line worker. The impact to productivity is enormous. The supervisors are constantly shifting workers around to meet the daily schedule. On the job training in a new role is a daily occurrence. Finally, continuous improvement is almost impossible; the workers are just trying to survive the day and get the job done.

7.3 Gaining Acceptance for New Ideas

In spite of these issues stated above, many aspects of the project were implemented, at least in part, in the plant. The reason for the success was the investment in time during the first few months to build trust with the workforce. A large amount of time was spent getting integrated into the workforce. The majority of the work took place with the material handling supervisors and workers group. The process of becoming integrated and building trust within the group was essential for the success of the project.

Many reasons stood in the way of integration of the author into the group of material handling workers at Cologne - national culture and language, company culture, educational background, etc. Ed Schein (1992, pp. 70-93), considered one of the founders of the field of organizational psychology, has developed six basic processes typically necessary for managing the integration of groups that can be used as a framework for the integration process of the author. The following are the processes and short descriptions of their relationship to the integration process:

1. Creating a common language and conceptual categories
   - The author definitely didn't share the same verbal or nonverbal language, in that he didn't fully understand the German culture.
   - The production team did not share a knowledge base in lean manufacturing. This led to training and lengthy explanations about the process to the workers, who were skeptical since it was far outside of their normal mode of operations.
The culture of the plant and the methods of getting things done was not obvious in the beginning of the research. The more people that were asked about a certain initiative, the more often you were told no.

2. Defining group boundaries and criteria for inclusion and exclusion
   - It seemed that the team hoped that the research project would pass without them having to change many of their processes and therefore did not at first want to help with the project.

3. Distributing power and status
   - The external power structure between the company supervisor, the plant FPS team, and other constituents such as the plant layout group seemed to play an important role in the politics of the situation.
   - The group had an informal power structure. There were several factors within it. First, ethnic background was one source of power. Additionally, seniority in the plant and job was another.
   - The receiving area supervisor was in a position of power to help promote the project since he knew the right people and had a great deal of experience. However, it seemed that others were not always so eager to work together.
   - The author had the label of Praktikant, or intern, from a German university. The title seemed to not have a very high status within the organization. This label was not exactly equivalent to the experience brought to the table by the LFM author given the 4 years of work experience and MIT training.

4. Developing norms of intimacy and friendship
   - Working together with the workers on the floor over several Saturdays to implement the marketplace developed a sense of trust and shared concern that helped out throughout the project.
   - Additionally, really listening to the ideas of the supervisors and the workers, a sense of trust and a good working relationship with the material handling supervisors was developed.

5. Defining and allocating rewards and punishments
   - During the research, the only rewards that the author could provide were friendly greetings or thank yous, however those did build credibility and trust.

6. Explaining the unexplainable - ideology and religion
   - The culture of the Cologne plant was a sort of ideology of "you scratch my back, I'll scratch yours." Continually, people tended to do favors for one another because of a good old boy network and not necessarily because of a business need.
   - Additionally, the FPS team at the plant thought that they had a brand new ideology (that of lean manufacturing) that they were implementing. The FPS team shunned any involvement from external resources.
   - The material handling group had an ideology of not letting the line stop. They should always have the parts just in case. That was the guiding principal for many years, so changing principals was difficult.

In the end, through persistence and using the trust that was formed, several improvements were implemented. The strategy used to implement the new techniques was to start in a small area of the plant and then expand from there once the concept was proved. An area of the trim lines was isolated and used as a test bed for implementing the marketplace. Based upon the April 1999 visit, the ideas and initiatives started during 1998 continue to function and have expanded. The supervisors have taken the ideas upon themselves to push forward.
7.4 Learning by Doing During This Research

There were many things that I learned throughout the process of this research. First, relationships are critical to getting things done. Next, implementing change is best accomplished in a small test area. Finally, the importance of maintaining focus within the research.

The successes that this project was able to achieve were primarily due to help that I received from all of the workers in the material handling group. They were the ones that had to change the procedures and work methods. Without their trust, nothing would have changed. I spent several months building relationships and earning the trust of the supervisors and workers on the shop floor. This time was invaluable since the result was that together we achieved results on the project.

Second, it is very important to limit the implementation of a new concept to a small test area so that you can evaluate the effects on the full system. This is particularly true in a plant with the size of Cologne. We initially implemented marketplaces for approximately one third of the material used by the plant over a two-week period. It worked, but only because there was a forklift driver that worked in the area that was twice as fast as the typical man. There were several problems associated with this initial implementation. Following the implementation of this original marketplace, the team implemented a second marketplace on a smaller scale using some best practices seen at other Ford sites and at Toyota. This marketplace was sized for parts from only one aisle of the plant and proved a more effective size on which to test the marketplace concepts. In the end, a marketplace concept that was functional and scalable was developed.

Finally, throughout the project it I found that it was important to stay focused on the goals. In many cases, this research was interrupted by some "firefighting" of daily problems or diversions into other mini-projects that arose. In each of these situations, while they did help to learn more about the system, the objectives of the project may have slipped as a result. As a corrective action, it is necessary to develop a timeline with key milestones and measure the progress of the project against that on a regular basis.
In summary, there were several key lessons that I am taking from the work presented here as I go forward. I will continue to work to develop trust and relationships within the area where I am trying to accomplish a task. Additionally, I will focus on small chunks of a project that can be scaled. Finally, maintaining a schedule with key objectives is critical to ensuring the timely success of a project.

7.5 Summary

Overall, the process implementing the new ideas was a bit frustrating. Building the trust was a difficult, but necessary step in the process. Cultural issues arose along several dimensions - traditional hierarchical management behavior, lack of communication among groups and my standing as an outsider. Learning the language and the culture was critical to adjusting to this environment. In the end the credibility of the ideas was also necessary along with a thick skin to take no for an answer. In the end, persistence was the primary reason any of the new ideas were implemented.
Chapter 8: Conclusions

8.1 Results Achieved and Conclusions

The Cologne assembly plant desired to improve the material handling processes by using lean manufacturing methods. Through the course of this research several different areas of the Cologne operations have been positively affected.

First, by proposing simple inventory controls using the Base Stock Model, a one time savings in working capital of $1,000,000 could be achieved plus an annual savings of $200,000 annually based on a 16% cost of capital. The system had inventory in the wrong place at the wrong time and the customer service level was low. By implementing the proposed methods, the assembly line should be able to have the required part 99% of the time. Additionally, as a side result, by lowering the level of inventory in the system, it should improve the focus on quality within the plant.

Second, the material receipt and storage processes were redesigned in some areas to improve the visibility of the process. Signs were used to organize parts into a specified place and the optimal inventory labels were specified. First in, first out material flow methods were implemented to improve the visibility of quality problems within incoming material. Finally, new receiving areas were proposed for closer receiving to the point of use. The result was a more visible process with smaller amounts of waste.

Linefeeding was the final area of focus. The system was redesigned from having drivers responsible for a function, such as recyclable container removal, into one where the drivers were responsible for all tasks related to a specific line of the plant. The new method was implemented in a test line in the plant with success. The drivers were more responsive to the needs of the assembly line. The number of parts that were expedited was reduced. Excessive inventory in the lines was reduced since the drivers were more aware of the requirements. Finally, the lines were clear from extra wagons that were left in the area by drivers that did not have a direct interest in the operation of the line.
In summary, the operations of material handling at the Cologne plant were significantly enhanced through the results of this work. However, the biggest achievement of the project was the fact that the material handling and assembly operations were exposed to the elements of lean manufacturing. Since leaving the plant, the foundation that was started through this project is beginning to expand. One aspect of improvement, since December 1998, is that more marketplaces were established as of April 1999. Additionally, the stockcheckers are becoming more accountable for the material stock levels and the drivers are helping to improve the service level of the line. Overall, even if the results of this research are carried no further, at least the plant has had the exposure to a new way of thinking about material handling.
References


