IMPLEMENTING LEAN MANUFACTURING IN AN AUTOMOBILE PLANT PILOT PROJECT

by

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Abstract

This thesis proposes a methodology to implement lean manufacturing methods in a traditional assembly plant. Changes in the competitive environment in the U.S. automobile industry have highlighted the advantages of the lean production system. These methods have proven successful when introduced in parallel with new plant start-ups. However, a different set of challenges is involved when introducing these methods to existing manufacturing factories that have been using mass production techniques for years.

The methodology was developed in a single plant and is not meant to be universal to all manufacturing facilities wishing to shift to lean production; however, the issues faced in this particular factory will most likely be common to many plants. The lean manufacturing implementation methodology was developed as an intermediate step towards truly lean manufacturing. This thesis describes the intermediate system and its advantages over existing plant systems. The intermediate system consists of new methods for designing assembly lines, handling material, and reducing errors. Through the use of this intermediate system, the plant will realize productivity improvements, inventory reductions, and quality improvements. Future improvements in the manufacturing system to reach true lean production are also proposed.

The full advantages of lean production cannot be reached without significant organizational change. In fact, organizational change is the greatest barrier to the implementation of lean production. A team structure is proposed to facilitate and support the pilot project. The successful transition of the manufacturing organization depends on the ability of management and union leadership to lead this difficult change.

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Stephen Graves, Professor of Management Science
Alvin Drake, Professor of Systems Science and Engineering

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Chapter 1: Introduction

This thesis presents a methodology used to implement lean manufacturing in a traditional mass production assembly plant. The methodology does not result in the plant's operations moving from traditional processes directly to lean production methods. Instead, the end result of the project can be thought of as a "walk before you run" concept. Because of the culture and some of the systems in place in the plant, it was felt that an abrupt change directly to lean methods would be too much of a shock to the system. This thesis presents the methodology used to implement an intermediate system and provides recommendations to move towards a leaner manufacturing system in the future.

This chapter will provide a framework for the entire thesis, beginning with a statement of the problem and the goal of the research project. The structure of the thesis will then be presented. The chapter concludes with an overview of the research findings.

1.1 Statement of the Problem

The competitive environment in the automobile industry has changed significantly in the last fifteen years. U.S. companies received a shock as many consumers moved towards high quality, low cost Japanese cars. This caused a rethinking of the way cars are produced; much has been written about the methods Japanese automobile companies use to build their vehicles. Advantages of these methods include higher productivity and quality, reduced inventories, increased flexibility and increased worker involvement in the production process [Womack, Jones and Roos, 1990]. An overview of these methods -- known as lean production -- will be presented in the next chapter.

Japanese transplants have shown that lean production can work as well in the U.S. as it does overseas. However, these plants were built on greenfield sites away from the traditional U.S. union environment. U.S. car and truck producers don't have the luxury of starting with a clean sheet of paper. The challenge for U.S. manufacturers lies in developing lean production methods in plants where traditional mass manufacturing has been in place for many years. The design of plant systems and the plant's established relationships with its workforce and its suppliers can be hindrances in the attempt to shift to lean production. This research project proposes a method that was used in one plant to shift towards lean production.

1.2 Goal of the Research Project

The goal of this research project was to develop a plan to implement lean production methods and then to evaluate the methods used to determine future directions for similar efforts. The methodology discussed in this thesis is not meant to be universal to all manufacturing plants wishing to shift to lean production. However, the issues dealt with in this particular facility will most likely be common to many plants.

An intermediate system was implemented for several reasons. First, because there was no team infrastructure in place to support the project, it was felt that a complete shift to lean production would not be feasible. The use of an intermediate system allowed the plant to begin to learn about lean production (and the efforts needed to implement it) while setting the stage for the eventual introduction of a fully lean system. Also, the intermediate system was designed to improve plant operations, using methods to improve productivity, reduce inefficiencies and improve product quality. Therefore, a goal of the project was not only to begin to introduce lean ideas to the plant's workforce, but also to introduce methods which would improve existing plant operations.

The research project was performed at Chrysler's Warren Truck Assembly Plant located in a suburb of Detroit. The research effort spanned a seven month period beginning in June 1995 and was performed by a team consisting of three college interns, plant management, and material handling and process engineers. The core team also interacted with industrial and design engineers, outside contractors, suppliers, production workers and production supervisors.

Lean manufacturing is a system encompassing production methods, vehicle design and relationships with suppliers and customers. This project does not explore the system to these depths -- the scope includes only the production methods on a plant floor and the delivery of parts to the manufacturing facility.

1.3 Structure of the Thesis

Chapter 2 of this thesis provides necessary background for the research project. Background of the pilot project, the plant environment and the Toyota Production System will be discussed. Lean production at a plant operations level encompasses process design, material handling, error avoidance and teamwork. Chapter 3 presents the methodology used to design the new assembly line and compares the new design with the current process. One component of assembly operations is the selection, or picking, of parts. This selection process can be improved by arranging material more efficiently at operators' workstations. Improved methods of arranging, or displaying, material to line operators will be examined in Chapter 4. Chapter 5 describes new methods which will be used to store material in the plant and deliver parts to the pilot assembly line. Techniques to reduce assembly errors will be examined in Chapter 6.

Chapters 3 through 6 describe implementation considerations for specific components of lean production systems. The major barriers to introducing the entire system to the pilot project are due to the plant organization and culture. Organizational culture and change will be examined in Chapter 7, and will provide recommendations to facilitate the shift to lean manufacturing. The thesis concludes in Chapter 8 with an overview of the research findings and recommendations for future work.

1.4 Overview of the Research Findings

The implementation of lean production methods to a pilot assembly line will be performed in parallel with a new product launch. There were several advantages to focusing introduction efforts on a small area of the plant, including the opportunity to try new methods and prove their advantages over existing practices prior to full-plant implementation. The level of risk is minimized and the ability to monitor system performance is improved through a small scale introduction. Process change is eased when performed in parallel with a product launch. Introducing new production methods on an operating process risks operation disruptions; a product launch typically requires process changes and funding is available to make these alterations.

The pilot production methods are expected to result in significant improvements over existing practices. A balanced assembly line will result in substantial productivity improvements. New techniques for handling material will lead to reductions in both inventory and inefficiencies. Error reduction techniques should increase quality. However, the system implemented on the pilot assembly line does not reach the full potential of lean production. It is only a first step.

There are several aspects of lean production that will not be introduced to the pilot project initially. The workforce is not organized into teams and without the support of teams, full implementation was not possible. The use of both line stop mechanisms for defect correction and standardized work procedures as a tool for continuous improvement are not recommended in the absence of a team infrastructure. The significant organizational change that must occur to support teams must be led by both management and union leadership and will take more time than this six-month research project allowed.

Chapter 2: Research Project Background

This chapter presents necessary background and a common language to be used throughout the thesis. A brief description of plant operations and the reasons for choosing this particular project for lean production implementation are first discussed. A brief description of lean manufacturing is presented, followed by a discussion of the plant environment in which the project was performed. The chapter concludes with an overview of the research methodology.

2.1 Project Background

The research for this project was performed at Chrysler's Warren Truck Assembly Plant (WTAP) where both the Dodge Dakota and Ram pickup trucks are assembled. An overview of the assembly process is shown in Figure 2.1. Trucks travel on a conveyor system throughout the entire process. Stamped panels are welded to the truck frame in the Body in White area of the plant. The steel frame and panels are then transported via conveyor through the Paint process and the painted bodies emerge into the main assembly, or Trim, area of the plant. All internal components of the truck are assembled in the Trim area. Examples of the components assembled to the truck include seats, instrument panels, headlights and carpeting.

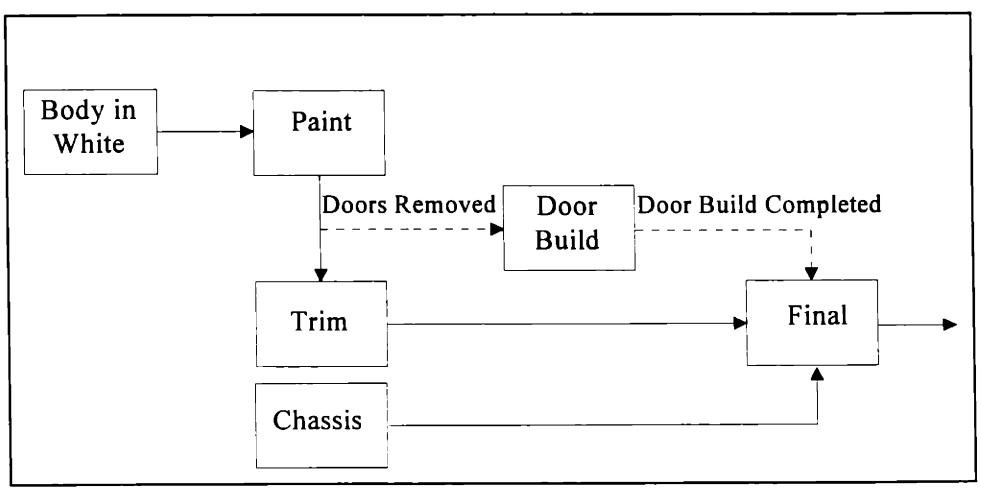


Figure 2.1: Process Overview

In parallel with the above process, the truck chassis -- consisting of the lower frame, suspension, transmission and engine -- is assembled. The truck chassis and assembled body are then mated towards the end of the process and the completed trucks are driven off the assembly line.

WTAP will introduce a new model of the Dodge Dakota in June of 1996. In parallel with this model changeover, the plant is shifting to a doors-off assembly process which is also shown in Figure 2.1. In the current assembly process, trucks move through the Trim area with the doors attached. In the new doors-off process, the doors will be removed from the trucks as soon as the vehicles leave the Paint area. The doors will then travel down a separate conveyor line where internal components (e.g. door speakers, windows, latches) will be installed. The completed doors are transported via overhead conveyor to the Final line where they are then reattached to the same truck from which they were removed.

The first doors-off assembly line was installed at Nissan Motor's Zama Plant in 1979 [Matsubara and Nagamachi, 1994]. Today, most automotive assembly plants have adopted the process. Benefits of doors-off assembly include:

The ability to move material on the main assembly line closer to the vehicles. This is made possible because vehicles no longer travel down the assembly line with the doors open; without the necessary clearance for the doors, material can be moved closer to the point of assembly. In the Zama plant, this action resulted in a 34% reduction in daily walking distance for the assembly workers.

The ability of a worker to walk parallel to the vehicle, as opposed to walking around an open door. In the Zama plant, this resulted in a 15-20% reduction in daily walking distance.

Improved assembly ergonomics for line operators. Vehicle access is enhanced and the installation of such components as seats and instrument panels is made easier with the doors removed.

Reduced door damage. The likelihood of an operator accidentally bumping into a door while holding a tool is reduced when the doors are mounted on carriers traveling down a separate assembly line.

In parallel with the model and process changeover, plant management saw an opportunity to introduce new production concepts to the plant floor. Attempts at lean production had had mixed results in other plants in the corporation, mainly due to an attempt to introduce large scale changes in those plants. Management at WTAP believed that a smaller scale introduction of lean production could be successful. The door assembly line was selected as the pilot project to implement these new process methods for the following reasons:

1. The risk level was minimized by limiting change to a small area of the plant
2. The capability existed to monitor the performance of the system because the process is isolated from the main assembly line and the complete process is performed within the door build area.
3. The ability to successfully implement new procedures was enhanced when accomplished in parallel with system installation.

Once lean production concepts are shown to be successful on the plant floor, the doors-off assembly line will be an example that the rest of the plant can follow. Management felt that this was the best way to disseminate new and improved methods throughout the plant: by first proving their feasibility and then by providing a model that the rest of the plant could emulate.

2.2 Overview of Lean Manufacturing

Much has been written about the Toyota Production System (TPS), also known as lean manufacturing. Taken as a whole, lean manufacturing encompasses areas including product design, supplier and customer relationships, and manufacturing systems [Womack, Jones and Roos, 1990]. The project at WTAP focused only on those aspects of TPS that are directly applicable to the operations of a manufacturing plant. This section serves only as an overview of these underlying concepts and is meant to establish a common language to be referred to throughout this thesis.

The Toyota Production System is a continuously evolving system that has been under development since the 1950's. Its basic tenet is to eliminate waste wherever it occurs with the end goal being to produce the highest quality products at the lowest cost. Lean production consists of the following concepts [Ohno, 1988; Shingo, 1989; Mishina, 1992]:

Minimize defects. Traditional manufacturing systems often have inspection stations in place at the end of a process. If a defect occurred early in the process, it would not be detected immediately, and the defective product would continue through the process, getting value added at each subsequent step. Consider the example shown in Figure 2.2. The process shown is an assembly line where Stations 1 through 6 consist of component assembly steps and Station 7 is an inspection process. A component is incorrectly installed in assembly Station 2 but the defect is not detected until Station 7. Once detected, the defective product is sent to a rework station. To repair the product, the components previously assembled in Stations 3 through 6 are removed and the defective component is repaired. From the time the defect occurred to the point it was repaired, four value-added steps were performed and subsequently removed and time was wasted transporting the product from station to station.

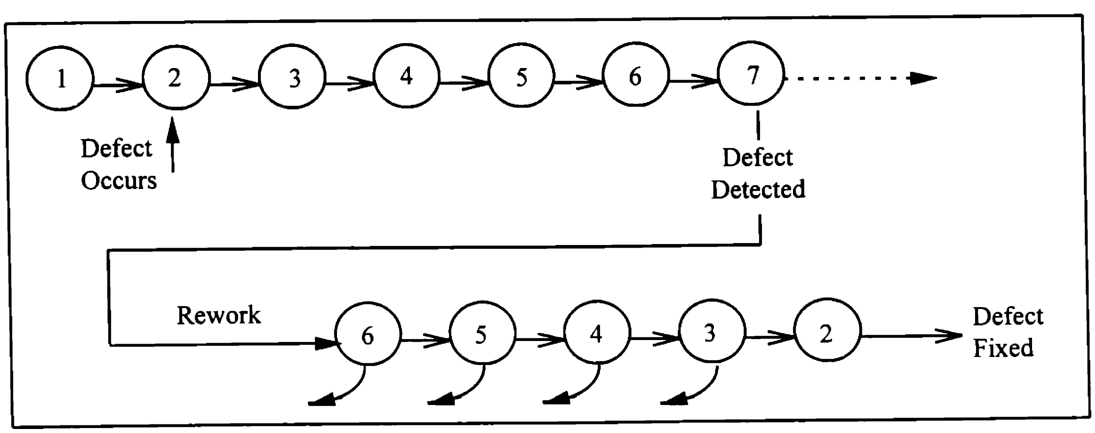


Figure 2.2: Rework Process

The Toyota Production System attempts to eliminate these inefficiencies. The potential for parts to be incorrectly assembled is reduced through product designs and parts selection systems which are designed so mistakes cannot be made. This is known as mistake-proofing. One example of mistake-proofing is a situation where two similar parts are given different patterns of fastener holes so that the incorrect part cannot be installed. Another example of mistake-proofing is a parts selection system at an assembly station that energizes a light above the correct choice of part.

In the event a defect does occur, it is detected and repaired immediately instead of continuing to other value-added steps. This is accomplished through the use of an andon line which is basically a mechanism a production worker can use to signal a defect. If a vehicle is traveling on a conveyor through an assembly worker's station and he or she has a problem, the andon line is pulled to alert the group supervisor of the problem. The supervisor comes to the assistance of the assembly worker and if they can repair the problem quickly, the andon line is pulled a second time and the vehicle continues to the next workstation. If the problem cannot be corrected before the vehicle leaves the workstation, the conveyor stops automatically and the team repairs the defect. Once the conveyor line is re-started, the root cause of the problem can be explored and corrective actions can be taken so the problem will not happen again. Through the use of the andon line, lean production ensures defects are identified and corrected at the source of the problem.

Deliver material just-in-time (JIT). Traditional manufacturing systems can call for the holding of large amounts of inventory. This inventory is needed to compensate for uncertainties in production schedules, large lot sizes, and infrequent deliveries from supplying operations. Lean production strives to reduce the holding of excess inventory by delivering only the necessary amount of material at the time needed, or just-in-time (JIT).

The tool used for JIT delivery is the kanban. A kanban is a signal, usually a card or an electronic signal, from an operation to the process immediately upstream. The upstream process only produces parts when signaled from the downstream operation that it is time to produce more parts. Parts are "pulled" to an operation on an as-needed basis. Information on a kanban card usually includes the identification and location of the upstream and downstream processes, the number of parts to deliver or produce, and the number of cards, or total inventory, in the system.

To facilitate JIT delivery from supplier plants, materials are delivered to TPS plants on a frequent basis. Instead of a truck making a trip to a single supplier plant and returning with a full load of material, a truck may pick up material from several sources and deliver a mixed load to the plant. To illustrate the advantage of this method, consider a case where mixed-load deliveries are made from four suppliers on four different occasions during the day as opposed to the case where each of the four supplier plants makes only one delivery to the assembly plant each day. If the supplier plants are in close geographical proximity, the same truck capacity can be used to deliver parts at four times the frequency to the assembly plant, thus reducing the amount of inventory held.

Minimize variation. Lean manufacturing attempts to minimize waste by minimizing the inherent variations in a manufacturing process. This also makes the system more predictable and therefore easier to control.

One way in which variation is minimized is through production leveling. Production is distributed evenly throughout the day which results in minimum inventory levels and maximum capacity utilization. This can best be seen through a simple example. Consider a facility that assembles three types of vehicles: A, B and C. The plant's daily production schedule calls for the assembly of 600 trucks broken down as follows: 300 A's, 200 B's, and 100 C's. The plant could assemble all 300 A's in the morning, 200 B's in the early afternoon, and 100 C's at the end of the day. If production were scheduled in this way, the plant's suppliers would need to carry large amounts of inventories to compensate for the large peaks. The plant would also have large finished goods inventory awaiting shipment to dealers. If instead the plant assembled trucks in a repeating sequence of ABABAC, both supplier and finished goods inventories would be reduced because the large production peaks would no longer exist.

If production were scheduled in large lots during the day, some workers and equipment would be working at capacity while others remained idle. By smoothing the production schedule as described above, work can be more evenly distributed across the plant's manpower and equipment. This allows the plant to maximize the utilization of its capacity.

Variation in utilization from workstation to workstation is also minimized. This is known as line balancing and results in the maximum productivity of the production line. As an example, consider a production line consisting of six workers, three of whom are working 90 percent of their cycle time and three of whom are working 60 percent of their cycle time. The sixth person's work could be redistributed to two of the workers, he or she could be reassigned to another area of the plant, and everyone on the production line would be working 90 percent of their cycle time. Through line balancing, TPS maximizes the productivity of the workforce.

Continuous improvement. Production workers at TPS plants work in teams. These teams are given ownership of their processes and strive to continuously improve the efficiency, quality, and working conditions of their operations. Depending on the system impact, the teams can implement changes themselves or they may need permission from team leaders or plant management. Suggestion systems are widely used to implement high-impact changes. Examples of continuous improvements include the elimination of unnecessary motions, inventory reductions, and the redistribution of work.

Standardized work procedures are tools used for continuous improvement. The information included in standardized work includes the amount of time an operator has to perform his or her job, the sequence of work, and the amount of in-process stock needed by the worker. Standardized work is developed by team leaders given input from members of the team. Teams then work together to improve the system, using standardized work as a baseline for improvement efforts.

Teams are flexible and members are cross-trained to perform each other's jobs. If a member is absent, the team leader can redistribute the workforce to perform the job and will work on the line himself if needed. Cross-training also gives the team the flexibility to redistribute work when needed without upsetting the system.

2.3 Plant Background

The purpose of this section is to give a brief description of the existing plant manufacturing processes and environment. Specific limitations noted with the manufacturing processes are not discussed in this chapter, but are instead reserved for subsequent chapters detailing the plant's systems.

Plant Environment

The Warren Truck Assembly Plant was built in the 1930's and has always assembled trucks. The plant is known within Chrysler as one of its most complex (building two entirely different vehicles on the same assembly line) and least progressive. The workforce is unionized and all production workers are members of the United Auto Workers (UAW) of America. Most workers have close to 30 years of seniority in the plant. The local UAW contract is not a Modern Operating Agreement which tends to be fairly flexible. Instead the contract is a more traditional one, which allows for many specific job classifications and does not specify the organization of workers into teams. The workforce is very hard-working; unfortunately some of the systems in place in the plant are not well designed and result in extra effort on the part the workforce.

The existing plant environment proves a challenge in the implementation of change. Largely due to the existing culture, a step change from existing production methods directly to lean production methods could not be accomplished. Instead, the results of the pilot project are a compromise between the potential of full implementation and the existing methods taking into consideration the changes allowed within the current organization. Organizational culture and change will be described in more detail in Chapter 7.

Manufacturing Processes

An overview of the entire manufacturing process was presented in Section 2.1. The purpose of this section is to discuss Trim operations in more detail. Trucks traveling on conveyors leave the Paint area and enter the Trim area, shown in Figure 2.3. The trucks travel through several parallel assembly lines (or "legs" of Trim) where internal components are assembled to the truck by operators stationed on both sides of the vehicle. Once a given truck reaches the end of one of the legs, it travels up a ramp, follows an arc which rotates it 180 degrees, and travels down another ramp to enter the next leg of Trim. The truck moves continuously and operators perform their assembly tasks by walking alongside the vehicle.

A truck typically travels through six to eight workstations in succession where operators perform their assembly operations. At the end of this sequence, the truck enters a Repair station (shown as "R" in Figure 2.3) where a senior repairman fixes any problems caused in the previous six to eight stations. This inspection and repair process is similar to that described in Section 2.2 and shown in Figure 2.2.

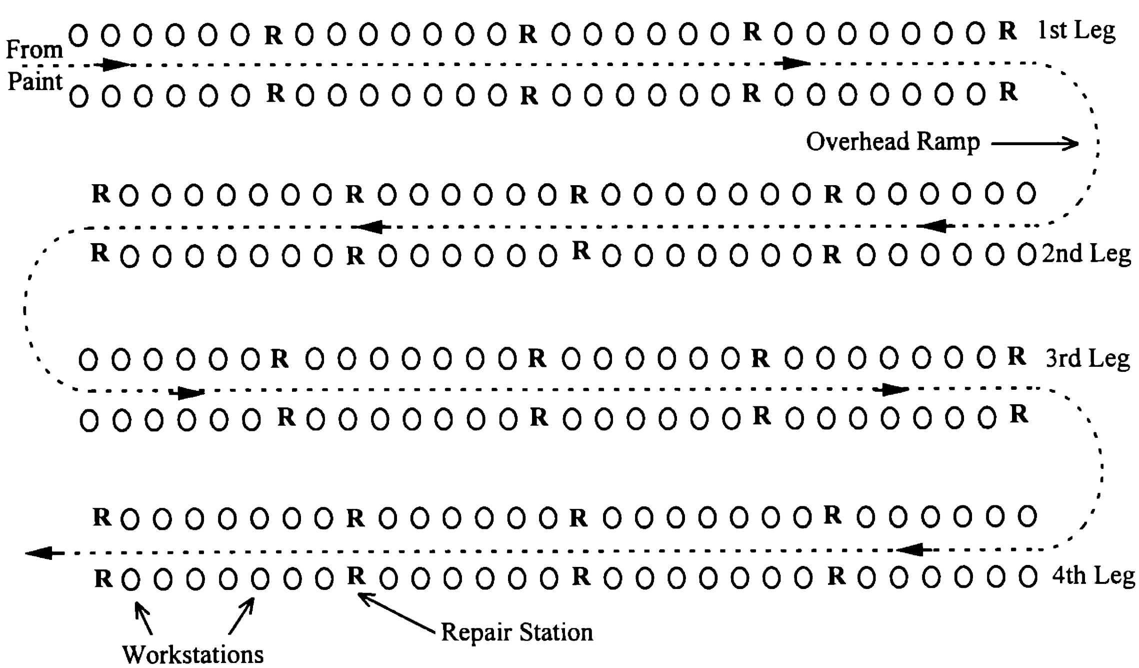


Figure 2.3: Overview of Trim Assembly Line

The plant production schedule is leveled as described in Section 2.2. Trucks of varying option content are spread evenly throughout the day. The plant produces a mix of 50% Rams and 50% Dakotas which will be shifting to 75% Dakotas and 25% Rams with the June introduction of the Dakota pickup truck. Production is currently leveled by building an alternating sequence of Dakotas and Rams, so a Dakota is built, followed by a Ram, followed by another Dakota and so forth. Each operator has a defined sequence of operations to perform on a Dakota and another set of tasks to complete on a Ram. Materials needed for these operations are located side-by-side at the operator's workstation.

The production schedule is set at the beginning of the assembly process -- in the Body in White area of the plant. However, due to variations introduced in the Painting process which are outside the scope of this thesis, trucks do not always leave Paint in the same order they entered the process. This variation can cause problems in Trim, particularly when several trucks with high option content (and therefore high work content) travel down the assembly line in succession. These problems will be discussed in more detail in Chapter 3.

Most parts for the assembly process are delivered to the plant at regular time intervals which are determined based on the current inventory levels in the plant, the expected usage, and the distance between the supplier plant and WTAP. Several large, high-value components -- such as axles and seats -- are delivered to the plant JIT if the supplier plant is located close to WTAP. Once trucks leave the Paint area, their sequence in the assembly process is set. JIT suppliers are kept continuously informed of the parts requirements via an electronic "broadcast" sent as soon as the vehicles leave Paint. Suppliers then ship the necessary parts to the plant in the same sequence they will be needed. The time window to ship parts is set from the moment the broadcast is received by the supplier to the time the part is to be assembled to the truck.

2.4 Overview of the Research Methodology

The first two months of the research project were spent benchmarking other assembly plants and gaining an understanding of the processes in place at Warren Truck

Assembly Plant. The research team visited five plants within the Chrysler Corporation and also visited Toyota's assembly plant in Georgetown, Kentucky. In parallel with these benchmarking trips, the team observed operations and collected data at WTAP. In order to implement lean production methods effectively, the team first needed to gain an in-depth understanding of the existing processes both to determine barriers to change and to understand the interactions any new methods would have with existing systems. The information the team collected included:

- Inventory levels
- Parts storage locations and movement throughout the plant
- Parts delivery frequencies
- Common problems in assembly and material delivery
- Sequence of assembly operations
- Interviews with plant personnel regarding system limitations

This information was presented to plant management along with recommendations to improve system performance. The areas targeted for improvement included workstation layout, material handling, material display, and mistake proofing. The team planned the implementation of these systems in a particular order. It was necessary to design the workstation layout first, because the order and placement of operations determined the placement of material along the door assembly line. Once the work content of each station was known, the part assignments for each workstation could be made. Given these part assignments, it was possible to design the material handling and display systems. The material display system was designed next, and the location of parts and number of parts per container were used as inputs to plan the material handling methods. Mistake proofing methods were determined in parallel with the material handling and display systems.

Each of the systems discussed above were designed considering the lean production concepts presented in Section 2.2. The use of teams was also examined to determine the feasibility of building a continuous improvement culture at WTAP. The concepts of lean production and the methods that were developed using these concepts are shown below:

Minimize variation:	Workstation layout, Chapter 3
Deliver material JIT:	Material display and handling, Chapters 4 and 5
Minimize defects:	Mistake proofing, Chapter 6
Continuous improvement:	Organizational culture and change, Chapter 7

Specific limitations in existing plant methods and proposed steps to reach lean production methods will be discussed in the following chapters.

Chapter 3: Determination of Build Order Sequence and Content

This chapter presents the methodology used to design the work content at each station of the doors-off assembly line. The chapter begins with a discussion of the current methods used to assemble a door. Some opportunities to improve the existing system are highlighted, followed by a discussion of the methodology used to improve the system. The chapter concludes with a comparison between the old and new systems which shows the advantages of the new design.

The design of the workstation layout for the doors-off line includes both the sequence of operations and the work content at each station. The end goal was twofold. First, it was desirable to design a balanced line -- in other words, a line in which all assemblers worked at about the same pace -- which maximized the efficiency at each workstation. This design would in turn maximize the efficiency of the entire assembly operation. The second goal of the design considered the difference between Dakota and Ram cycle times at each individual workstation. It was beneficial to minimize this difference for reasons discussed below.

3.1 Description of the Current Door Assembly Process

Dodge trucks currently travel down the assembly line with the doors attached. As a truck moves through the Trim area, operators are stationed on either side of the vehicle, one person performing an assembly operation on the right-hand side of the vehicle while the other performs the identical operation to the left-hand side of the truck. The truck doors are not assembled in one continuous area of the plant, but are instead assembled at several stations spread across the first three legs of Trim as shown in Figure 3.1. Only those stations which perform assembly operations to the door are shown. Repair stations (shown as "R") are located every six to eight stations and are also shown in Figure 3.1.

The work content at some workstations consists solely of operations performed to the door; these stations are shown in black in the figure. At other workstations, operators perform some assembly operations to the door but also assemble some components to the

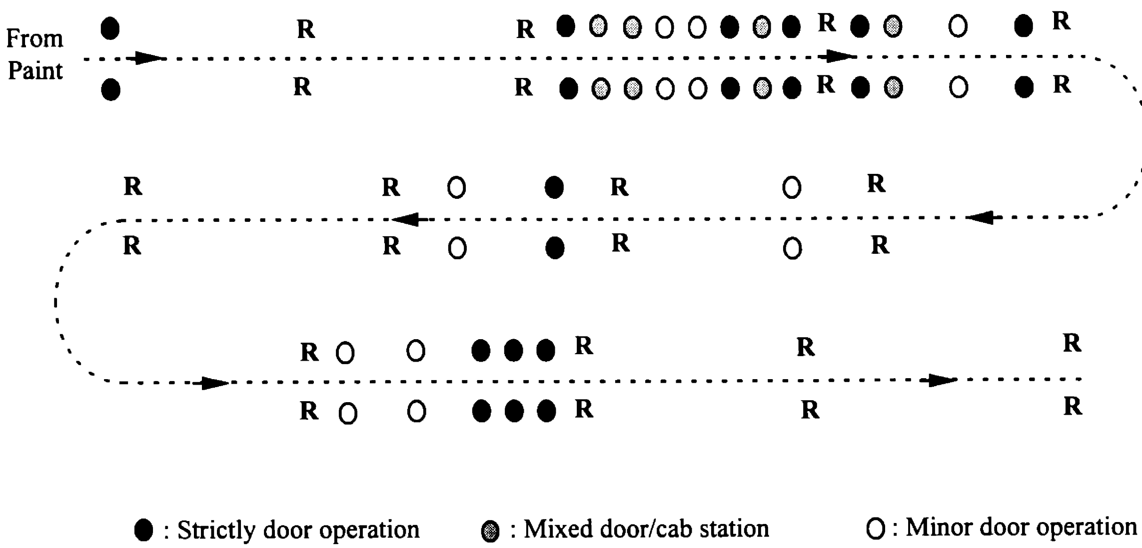


Figure 3.1: Existing Door Assembly Process

truck cab. In Figure 3.1, those stations with a significant door assembly operation are shown in gray and stations which perform only minor door operations are shown in white. The majority of the Trim workstations (not shown in Fig 3.1) do not perform any door operations. In order to design the layout for the new door line, each door operation was examined separately from the rest of the truck assembly. The door operations were then combined to form one continuous door assembly line.

Figure 3.2 shows the operating efficiency at each workstation for the existing door assembly process. Given a fixed truck conveyor speed and 20 feet of space along the line in which to work, every operator has 60 seconds to complete his or her operation from the time a truck enters the workstation to the time the truck leaves the workstation. Operating efficiency is defined as the percentage of the 60 second cycle time that the worker is occupied. This includes the time it takes for a person to pick up parts, walk to the door and perform the assembly operation. Figure 3.2 displays the operating efficiency for both the Dakota and the Ram operations for each workstation that performs an operation to the door. Workstations 1 through 14 are primarily door assembly operations (shown in black and gray in Figure 3.1) while stations 15 through 21 consist of minor door assembly operations (shown in white). The operating efficiency for all stations includes only the time it takes for a person to perform door assembly operations.

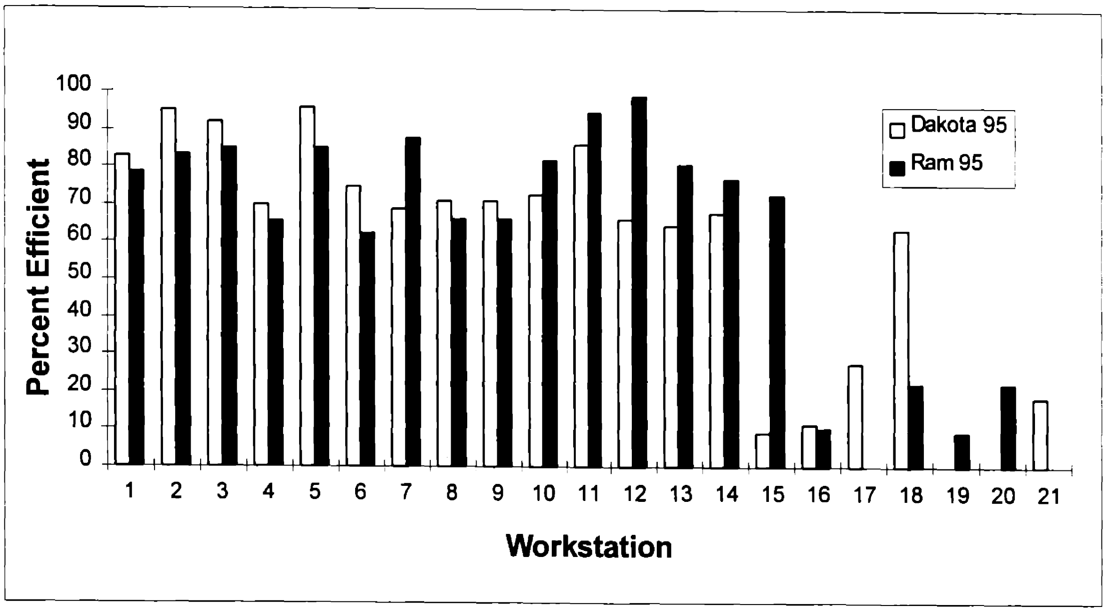


Figure 3.2: Ram vs. Dakota Door Workstation Efficiency 1995

Examination of the operating efficiency for workstations that are primarily door assembly stations (1 through 14) reveals two characteristics of the current assembly process:

1. The operating efficiency varies greatly from station to station
2. The difference between the efficiencies of Dakota and Ram operations vary greatly within workstations.

The first characteristic results in some workstations being very efficient and others being very inefficient. The second characteristic can result in operators working out of their workstations for reasons described next.

An example is used to describe the possibility of operators working into the next workstation. Workstation number three is 92% efficient and 85% efficient at assembling the Dakota and Ram doors, respectively. But in addition to door assembly operations, workstation number three also calls for the operator to perform one operation to the cab of the truck. This additional operation results in a total operating efficiency of above 100% for Dakota operations, while the Ram operation remains below 100% efficiency. Overall, the average efficiency of the workstation remains below 100%. This results in a worker getting slightly behind his work pace while working on a Dakota, but he is able to catch back up to pace when the following Ram enters his station. However, the sequence of trucks does not always alternate between Ram and Dakota.

As described in Chapter 2, the sequence of trucks within the plant is scheduled to balance the workload as much as possible, which results in Ram and Dakota trucks traveling down the assembly line in alternating sequence. However, due to problems in the Paint Shop, this sequence is sometimes broken which can result in multiple Dakotas or Rams traveling down the line in groups. As an example, consider a situation where the alternating sequence of trucks is broken by three Dakotas traveling down the line together. Without a Ram following every Dakota, the operator at station three is not able to keep up with his assembly operations. Working on three Dakotas in a row, each of which mandates that he works more than the 60 second cycle time, causes the operator to work into the next workstation. This causes the worker from station three to hinder the operator at the next station from performing her assembly operations.

The situation described above for station three would become the norm as the plant shifts from a production mix of 50 percent of each truck to a mix of 75 percent Dakotas and 25 percent Rams. This production mix change will occur in parallel with the new product launch in June. Therefore, one goal was to design the doors-off assembly line to be unaffected by a mix problem.

3.2 New System Design Methodology

The current plant industrial engineering time standards were used to design the new doors-off assembly line. The current time standards were still accurate for the Ram because its design remained unchanged. However, for the new Dakota pickup truck, the new parts were examined and the information used was a combination of current time standards for both the Ram and Dakota, depending on which design most accurately reflected the new Dakota design.

For each current workstation, door assembly steps were isolated from the remainder of the workstation and broken into three categories: value added, non-value added, and waste. Value added steps are defined as operations where the assembly worker directly adds value to the door, such as when parts are assembled into the door. Non-value added steps are those in which the operator performs a necessary operation, but it does not add value directly to the door. Most non-value added steps consist of a worker picking up parts or tools. Finally, waste is any operation not fitting into the first two categories and which it is desirable to reduce as much as possible. Most waste along the door line consists of walking to pick up parts or tools.

An example calculation of workstation content is shown below with time standards in minutes. Value added (VA), non-value added (N-VA) and waste (W) activities are also shown.

Window Regulator Installation for Dakota Doors:

Walk to truck	0.04	W
Read build order	0.02	N-VA
Walk to obtain material	0.04	W
Obtain parts	0.03	N-VA
Walk to workbench	0.03	W
Obtain tool	0.03	N-VA
Walk to truck	0.04	W
Align regulator to door	0.15	VA
Secure regulator using 4 screws	0.30	VA
Connect power regulator to wire harness	0.08	VA
Walk to computer terminal	0.04	W
Hit appropriate key	0.02	N-VA

Totals:
0.19 waste + 0.10 non-value added + 0.53 value added = 0.82 total time

Based on a 60 second cycle time, this workstation is 82 percent efficient with 19 percent of the cycle time being wasted and ten percent non-value added.

A calculation similar to the one above was performed for each workstation that performed an operation to the door. Operations were then resequenced and combined to form the new workstation layout based on several constraints:

Sequence constraints: While there was a fair amount of flexibility in the design, many operations had to follow a specific sequence. This sequence is mainly set because of access considerations. As an example, the door wire harness has to be installed before the window because once the window is in place, it is impossible to install the wire harness.

Ergonomic constraints: It was desirable to set the operations so that the majority of an operator's steps occurred in one section of the door. This would reduce the amount of bending and standing on the part of the operator. One workstation was specifically designed with the door elevated above the worker because all operations at that station were performed towards the bottom of the door.

Time constraints: Because each operation takes a discrete amount of time to perform, the addition of one operation to a moderately efficient workstation could raise that station's operating efficiency above a feasible level.

The new layout was designed within the above constraints to maximize the efficiency of each workstation while minimizing the difference between Ram and Dakota cycle times at each station.

Finally, some redundant operations that are performed on the current line were removed. One example concerns a water seal that is placed over the entire internal access area after all components have been installed. The current line requires the water seal to be peeled away from one corner to install an internal part. The internal part is installed before the water seal in the new line design to eliminate the need to peel and reapply the corner of the water seal.

3.3 Comparison Between Old and New Designs

A schematic of the new doors-off assembly line is shown in Figure 3.3. Those stations in dark type are essentially unchanged from the current process, with any changes in operating efficiency being attributed to the new Dakota truck design. Those stations that were the most efficient in the old design are still the most efficient -- *the operating efficiency of other stations have simply been brought closer to those efficient stations.*

Figure 3.4 shows the operating efficiency of the new design. The new design increases the overall efficiency for the Dakota and Ram assembly processes from 77 to 85 percent and from 80 to 86 percent, respectively. The average difference between Ram and Dakota cycle times at each station have been reduced from 11 to 2 percent.

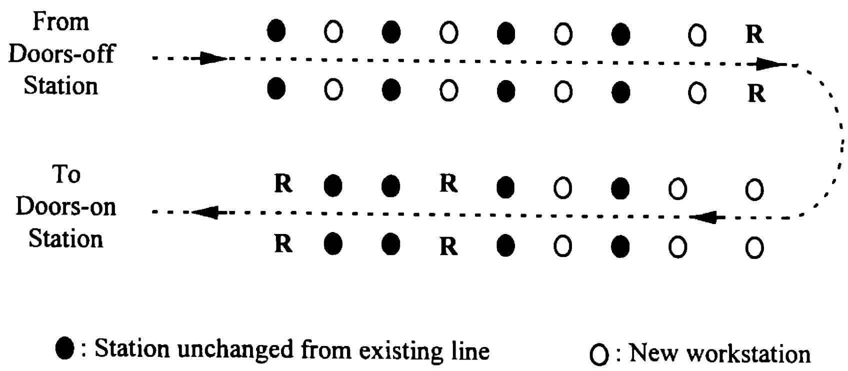
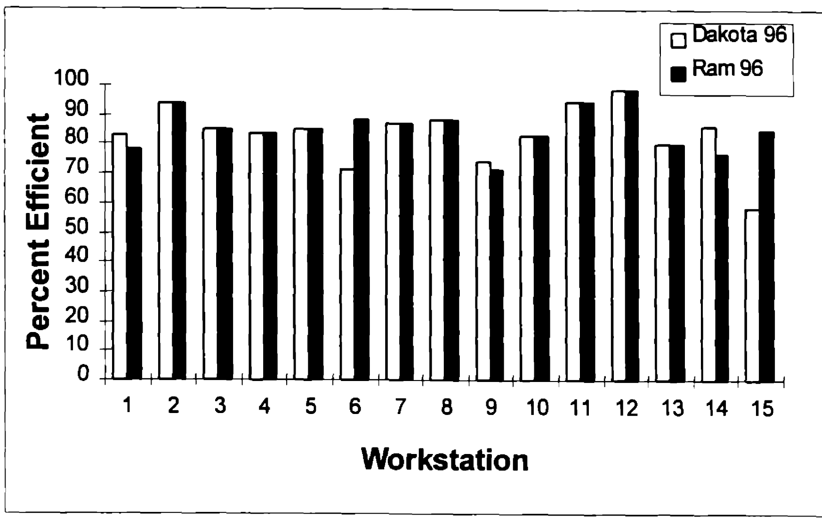


Figure 3.3: New Proposed Door Assembly Line

The original design of the doors-off assembly line estimated 17 stations needed to complete the door assembly. This original line was designed in much the same way as other lines have been designed in the past: the same workstations and sequence were reapplied to a new line without examining potential improvements. Due to the increased efficiency of the new doors-off assembly line, the number of workstations has been reduced by two over the original estimate. Given two people per station on two shifts, this results in eight people the plant does not need to hire.



	Ave	Std Dev
1995:		
Dakota	77	11
Ram	80	11
Differ	11	8
1996:		
Dakota	85	8
Ram	86	7
Differ	2	5

Figure 3.4: Ram vs. Dakota Door Workstation Efficiency 1996

In addition to improvements in assembly efficiency, it is believed that large productivity improvements can be made by changing the material delivery and display systems in the plant. The material display methods are examined in Chapter 4 and will offer solutions for eliminating the waste component in assembly operations.

Summary

On the existing assembly line, there are several very efficient workstations. However, there is also a large difference between these stations and others along the line. One purpose of the new door line design was to equalize the operating efficiencies of all stations closer to the level of the efficient workstations. By balancing the assembly line at a higher efficiency, truck doors will be assembled with two fewer workstations than initially estimated.

The door line was also designed to be insensitive to product mix. In the event that a group of same-model truck doors travel down the line together, workers will no longer get behind in their work and disrupt operations at downstream workstations.

Other than some productivity improvements due to re-ordering a few assembly operations, the gains discussed on the doors-off assembly line can all be attributed to a better-balanced line. The design did not take into consideration the reduction of the waste component in assembly operations. The next chapter deals with improving this component of production, namely the waste that can be attributed to the distance workers walk to obtain parts.

Chapter 4: Improvements in Material Display

In a high volume assembly process, eliminating inefficiencies in the processes operators use to select parts for assembly can result in significant productivity improvements. Once a cycle, operators must obtain parts to assemble to the truck doors. This selection process can be a significant component in the total assembly time of a vehicle and is a major contributor to wasted time in assembly operations as mentioned in the previous chapter. This chapter presents improvements made in the way material is displayed, or presented, to the operators working on the doors-off assembly line.

The chapter begins with a discussion of the current method used to present material to the operators. Following a discussion of the problems inherent in these methods, a new technique for material display is presented. The chapter concludes with a discussion of issues considered while implementing the new system.

4.1 Description of the Current Material Display Methods

The majority of door components are delivered to the plant in large 4'x 4'x 4' plastic returnable containers. These containers are delivered to the assembly line via forklift and are placed either on the floor or on six-inch high racks. When assembly operators select parts, they walk to the containers, bend over if the container is partially empty, and pick up the part to be used. Once empty, the containers are removed from the line via forklift and are brought to the shipping dock to be returned to the supplier. The supplier reuses the containers for later shipments to WTAP.

Those parts that are not delivered to the plant in large returnable containers are shipped in cardboard boxes. Operators select their parts from these containers and the empty cardboard boxes are recycled. The plant has been shifting from cardboard boxes to returnable containers to reduce both recycling costs and parts costs (the cost of cardboard is added to parts costs; Chrysler buys the plastic containers which can be used for many shipments). The material display at one workstation is shown in Figure 4.1.

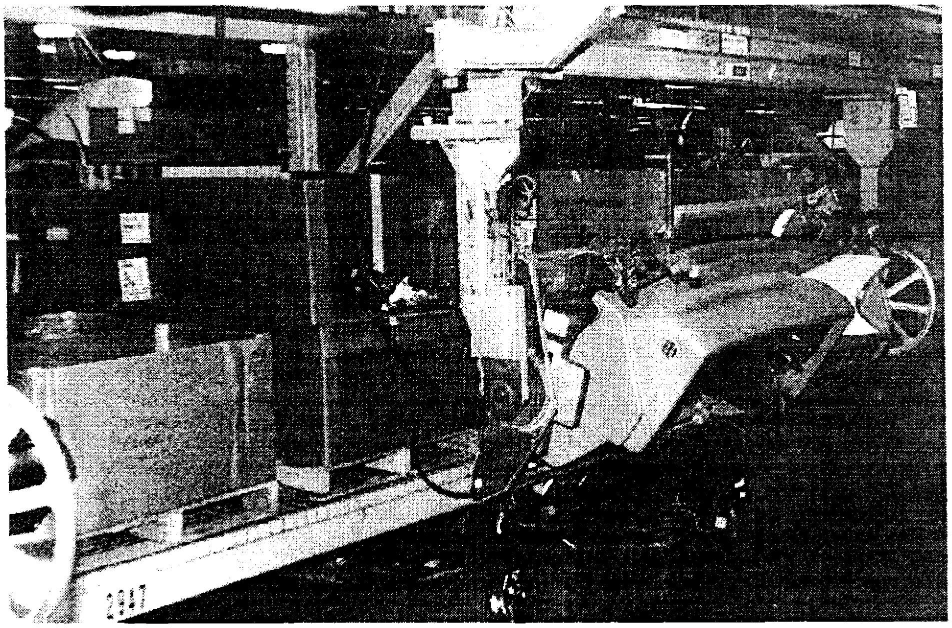


Figure 4.1: Example of Existing Material Display Methods

There are several deficiencies in the method of material display described above. An example of a typical workstation is shown in Figure 4.2 and reflects an actual material layout observed in the plant. Each square represents one large returnable container. The assembly worker has a choice of four parts: Dakota option A, Dakota option B, Ram option A, and Ram option B. The numbers one through four next to each box order the parts by the frequency of usage of the part; Ram option B (number 1) is the most frequently used part and Dakota option A (number 4) is the least frequently used part. To minimize the distance operators walk to obtain parts, the most frequently used components should be placed at the beginning of the workstation, or as soon as the door enters the station. Instead, the placement of parts is random along the line. For example, the operator installing components into the left-hand door has the least frequently used part placed in the location which should be reserved for the most commonly used part. This operator must walk an additional eight feet every time he or she selects Ram option B.

In addition to the placement of parts, this method of material display is inefficient based solely on the distance operators walk to obtain parts. In the example, parts display will cover a distance of 16 feet of line space at a minimum. If the operator on the left-hand side of the line empties the closest container of Ram option A, he or she will need to walk 20 feet to select that part until a forklift driver has the chance to remove the empty container and replace it with a full box. Without an organized system in place, parts will not be located optimally and multiple containers of the same part will be stored along the line.

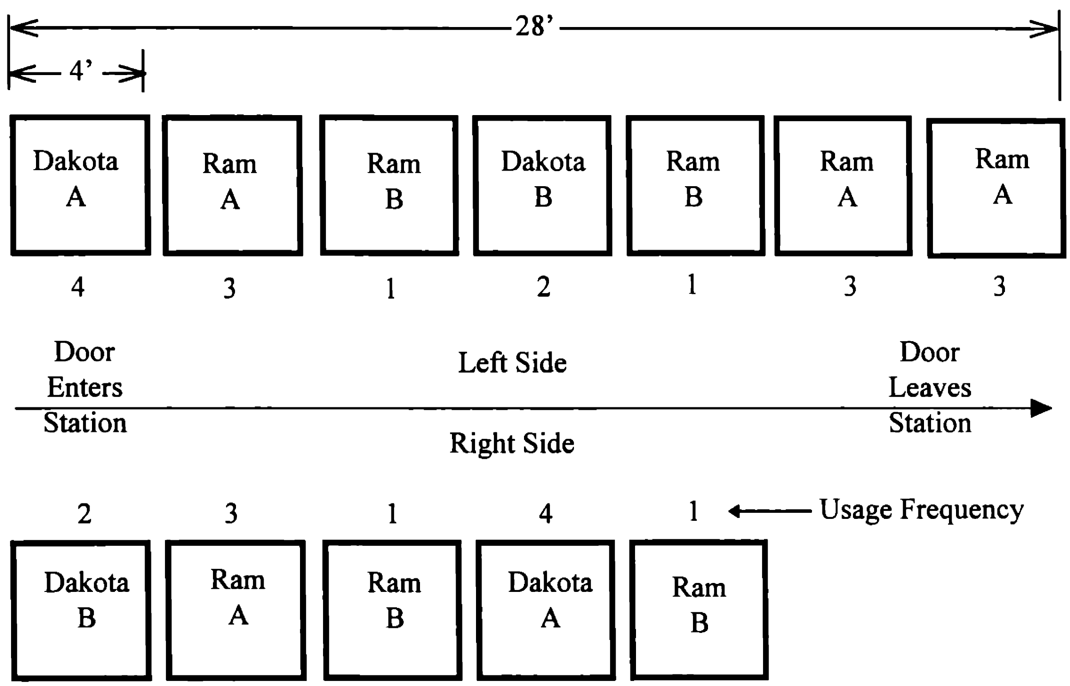


Figure 4.2: Typical Workstation Using Existing Methods

Also, to minimize walking distance, operators sometimes grab handfuls of parts and leave them in some convenient location (usually either a work table or the closest box of parts) near the beginning of their workstations. Not only is time wasted double-handling parts, but also the possibility of confusing parts and installing the wrong component is increased. In summary, the existing material presentation methods are inefficient because:

1. Parts in large containers take up vast amounts of line space and result in excessive walking on the part of assembly operators.

2. Containers placed directly on the floor or on short material racks are not

ergonomically sound because operators need to bend over to remove parts from partially full containers.

3. Frequently used parts are not placed closest to the beginning of workstations, resulting in additional operator movements.
4. Parts can have more than one location along the line, resulting in excessive inventory storage.
5. Operators double-handle parts, increasing the likelihood of accidentally installing incorrect components.

In parallel with the introduction of the doors-off assembly process, improved methods of material presentation were introduced to the plant.

4.2 Description of Improved Material Display Methods

Many of the inefficiencies in the existing material presentation methods are caused by the use of large containers. For the new doors-off line, the majority of parts will be delivered to the plant in smaller containers, or totes. Several of the plants that the research team visited received parts in large containers and then repacked these parts in totes within the plant. The research team decided to obtain parts in small containers directly from suppliers so this repacking would not be necessary at WTAP.

A representative sample of the totes used for door parts is shown in Figure 4.3. The base of the container pallet in the figure measures 4'x 4', which is the same dimensions as the base of one returnable container currently in use at WTAP. The use of smaller containers will allow for a much denser line display than available through the use of large returnables.

Each door part was assigned a specific-sized tote, considering both part size and weight. The tote needed to be large enough to hold the part, while not being so large as to result in wasted space. Along with maximizing the density of packing, each tote was required to weigh less than 30 pounds when full so operators and material handling personnel could pick up the boxes easily.

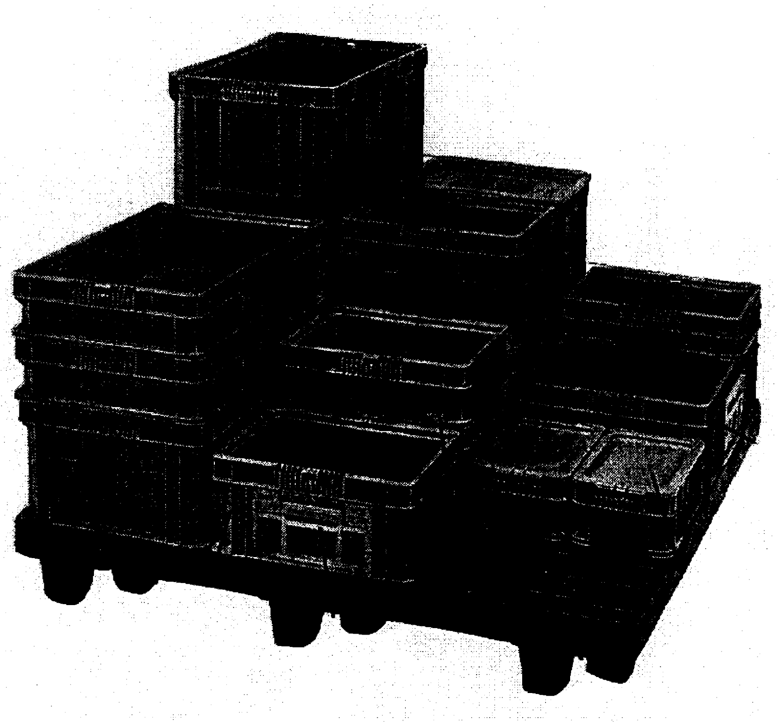


Figure 4.3: Example of Totes

Totes will be displayed to operators in roller racks as shown in Figure 4.4. Each roller rack consists of three levels. Two of the levels are tilted towards the line operators and are placed at a height which allows the workers to comfortably select parts. Material handling personnel replenish stock by feeding small containers onto these two levels through the back of the rack. The small containers travel on rollers and are gravity-fed to the operators. Once an operator empties a container, he or she places the empty tote onto the third level. This third level is tilted away from the operator; the empty tote travels on rollers away from the operator and is later removed from the rack by a material handler. The use of roller racks increases the density of parts storage along the line which in turn minimizes the distance workers need to walk to select components.

Within each roller rack, every part has a specific storage location. Labels containing the part number and description are mounted below each location on both the front and back of the rack. The labels on the front of the rack are meant as a selection aid to the assembly worker and the labels on the back of the rack aid material handlers in placing the correct parts into the rack. The location of each part within a rack can be designed so that the most frequently used parts are placed closest to the operators.

Figure 4.4: Example of Roller Rack

Maintaining the system and ensuring that parts are only placed in the racks (and not stacked on the floor) requires a certain discipline which will be discussed in more detail in Chapter 7, Organizational Change. If discipline can be maintained in the system, this new method of material display has the following advantages over the existing system:

1. Parts delivered in smaller containers and placed on roller racks allow for much denser parts storage along the line. This reduces the amount of walking performed by operators to pick parts.

2. Containers are placed at an elevation that improves the ergonomics of the parts selection process.

3. Frequently used parts are placed closest to the operators, reducing unnecessary movements.

4. Each part has only one location at a workstation. This reduces unnecessary inventory storage along the line.

5. Parts are placed close enough to operators so that the desire for double-handling will be eliminated. The likelihood of incorrect parts installation is reduced because parts will no longer be mixed at the workstation.

A description of an improved method of material display has been presented; the implementation of this new system is discussed in the next section.

4.3 Implementation of the Improved Material Presentation Methods

The doors-off line proved an excellent opportunity to introduce the new material display method. Many small components are assembled to the door and had been delivered to the plant in large containers. A single large container may hold between eight hours and a week's supply of material. By shifting to smaller containers, most parts were delivered in totes holding between a half hour and three hours' worth of material. This feature of smaller containers can aid inventory reduction efforts. As an example, consider a part which is delivered in a single large container holding a three day supply. The same number of parts can be shipped in twelve totes holding four hours' supply each (assuming two eight-hour shifts). Delivery frequency could be increased to once per day and the plant could reduce its inventory of that part from three to one day's supply. The door line was also a good application of the use of totes because most door components are lightweight. Small containers could be filled to capacity with most parts without reaching the 30 pound weight limit.

The doors-off process is being introduced to WTAP in parallel with a Dakota model changeover. There are very few parts being carried over from the old model to the new model, so the corporation needed to buy new containers for all Dakota parts. With a container budget for the Dakota already funded, it was desired to change Ram containers from large returnables to totes. A plant continuous improvement fund was used to pay for the totes needed for the Ram door parts. A series of stackable containers sharing a common pallet (Figure 4.3) was chosen to hold door parts. This system offered a number of different sized totes and a stackable system which allowed containers to serve as covers for totes below, thereby minimizing the likelihood of parts damage.

The majority of parts along the door line were assigned to be shipped in totes. Parts were designated to totes considering a tradeoff between the following factors:

Part size. Parts were assigned to the smallest totes available. The largest tote measured 32 inches long, so any parts longer than this had to be shipped in large containers.

Part weight. The total weight of a full container could not exceed 30 pounds. The weight limit was selected to allow material handling personnel to pick up full totes with relative ease.

Commonality between suppliers. In the event that a single supplier plant manufactured more than one door component, the same container was assigned to all parts delivered from that plant. This factor reduced the complexity in the supplier plant by minimizing the number of totes handled at the site. This requirement was met where possible, but in the event that the components were vastly different in size or weight, more than one tote was selected for use.

Commonality between models. If a part was common across Chrysler models and it was a frequent option on these models, a tote was not assigned. The budget for container procurement was limited, and if a part was shipped to multiple plants, it would be required to buy totes to supply all plants. Some suppliers did not increase parts prices to ship their parts in different containers to different Chrysler plants: in this instance, totes were assigned.

Part usage. High usage parts were not always assigned to the smallest available tote. If a tote held less than one-half-hour's supply of material, a larger tote was assigned. This criteria was selected to minimize the number of times material handling personnel would need to restock the roller racks.

Packing density. Containers were selected to maximize the density of parts packing and therefore to minimize the "air shipped." Containers were available in different heights, and a taller tote may have been selected over a shorter tote to maximize parts density.

Supplier distance from WTAP. Geography had an impact on container selection. Several suppliers of door parts were located far from the plant. In the event that a supplier plant was located greater than 300 miles from WTAP, parts were shipped in cardboard containers. As the number of days to ship parts to WTAP increases, the number of totes (or buffer stock) that must be bought to compensate for longer shipping delays increases.

There are a total of 124 parts along the door assembly line. Of these parts, 64 percent will be displayed in totes, 27 percent in large containers, and nine percent in cardboard boxes. Of the 34 parts which will be delivered to the plant in large containers, 16 parts were too large to fit into any of the available totes. The remaining 18 parts were assigned to large containers because at least one of the above listed factors became an overwhelming consideration in favor of large containers. Door mirrors were placed in large containers because these parts are common to many Chrysler models and because their geometry resulted in a significant reduction in density -- and a corresponding significant increase in shipping costs -- if they were shipped in totes. Door window regulators are fairly bulky and weigh five pounds each. A single tote weighing less than 30 pounds would only contain about a 15 minute supply of inventory. Because of this, regulators will be shipped to the plant in large containers.

The team decided to use a lightweight and flexible pipe and joint components system to build the roller racks. The plant materials handling engineer designed the roller racks and several racks were built to prototype the new methods on the existing line. The team chose several workstations along the line at which to prototype the new system. At these stations, parts were removed from their existing containers and placed in totes. The totes were then placed in the roller racks and operators were asked to use the system for a shift and give the team feedback on the system. Team members restocked the racks every two hours. Operators were enthusiastic about the system and gave the team very positive feedback. Some comments included: "I've done a lot less walking, my feet feel better today..." and "I can just turn around and pick up my parts, I don't have to walk up and down, bending over boxes...". One woman left the following note to her counterpart on the second shift: "Give this new rack a try. It's supposed to reduce walking and bending over. My feet feel much better after using it -- get used to it, this is the way of the future!" The opportunity to prototype the new racks allowed operator feedback to be incorporated into the new rack design: the shelf heights were changed slightly and locking wheels were installed which allowed the racks to be moved to facilitate cleaning.

An example of the material layout at one of the doors-off workstations is shown in Figure 4.5. Parts A, B and C are located in one roller rack, with part A on the bottom tier and parts B and C on the second shelf. Parts D through G occupy the second rack, with parts D and E on the lower level and parts F and G on the second tier. This same material occupies a minimum of 24 feet of line space using the existing methods. Using roller racks and totes, the material occupies eight feet of line space. The most frequently used parts (A, B and C) are placed closest to the beginning of the operator's station while parts G and E are infrequently used and placed farthest from the operator. Assuming 60 trucks built per hour over an eight hour shift, the new system reduces the operator's walking distance by 1.5 miles per day.

Although the new material display system is expected to result in significant waste reductions and corresponding productivity improvements, its use did not result in a reevaluation of the workstation layout. Had the line been re-balanced considering the waste reductions made possible with the new display methods, the number of workstations needed to build a door may have been reduced further. There were two reasons for not performing this redesign. First, plant industrial engineers were hesitant to reduce the number of workstations further because they were uneasy about running too lean with the introduction of an unknown process and a new product. Secondly, there was a concern that the introduction of a line that was significantly more productive than the old process would result in increased operator resistance which would jeopardize the introduction of the new production system.

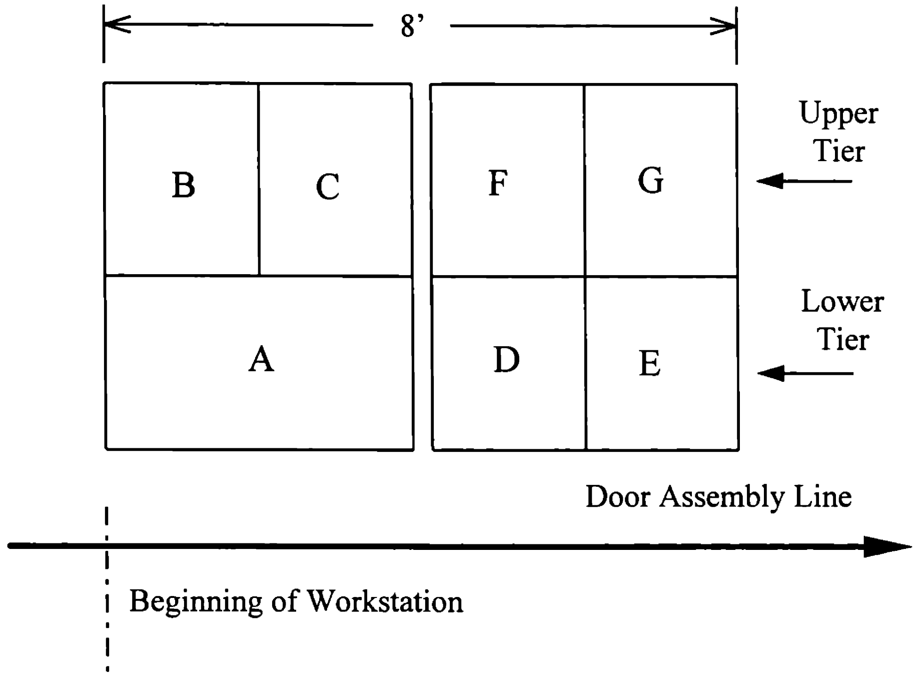


Figure 4.5: Material Layout Adjacent to Door Assembly Line

Summary

A material display system using totes and roller racks will be introduced in parallel with the doors-off process. The purpose of this system is to remove the inefficiencies inherent in the existing material presentation methods. Several tradeoffs to be considered when assigning parts to small containers were discussed as well as the advantages of prototyping the methods and gaining operator feedback prior to full introduction.

The full benefits of the system will not be realized immediately. Productivity improvements will be established in the future; in the interim, the new methods will increase operator comfort while reducing confusion, line inventory, and the potential for installation errors.

Chapter 5: Improvements in Material Handling

The previous chapter examined improved methods for presenting material to the assembly operators. This chapter discusses improvements in the methods used to deliver this material to the door assembly line. The chapter begins with a discussion of the current material handling methods. Several opportunities to improve the existing system are discussed, followed by a discussion of the proposed material handling methods.

Material handling includes the delivery of parts to the plant, the subsequent in-plant storage of these parts, and the ultimate delivery of components to the assembly line. The goal of the new material handling system was twofold. First, it was desirable to eliminate inefficiencies in the existing material handling system. The second goal was to develop a system which facilitated future inventory reduction efforts.

5.1 Description of the Existing Material Handling Methods

Delivery of material to the plant. Deliveries are made from both "straight" trailers, or trucks carrying single commodities, and mixed-load trailers. As discussed in Chapter 2, several components are delivered to the plant JIT. All other components are delivered at regular intervals. The intervals and shipment quantities are determined based on expected usages and the distance between the supplier plant and WTAP. Frequencies and shipment quantities are continuously adjusted based on the current inventory levels in the plant. Every night, 18 people count the inventory level of every part in the plant and enter the levels on handheld computers. People performing this "midnight count" estimate the number of parts in partially full containers.

In-plant storage of parts. Once materials are unloaded from the trailers, they are transported via forklift or automatic-guided-vehicle to one of two locations: a spot along the assembly line or an intermediate storage area. The majority of parts are transported to one of the intermediate storage areas (also known as drop zones) which are located at various points throughout the plant. There are eleven drop zones in the Trim area, four of which are used for door part storage. Each part is assigned to the drop zone located closest to its point of use and this assignment is printed on the shipping label by the supplier. A drop zone is simply a large area set aside for the sole usage of material storage.

Delivery of parts to the assembly line. "Stockchasers" are responsible for keeping the assembly line stocked with material and their main role is to ensure the line does not stop due to a lack of parts. Stockchasers use a "hot list" to prioritize their efforts. The hot list highlights those parts with low inventory levels and is generated every morning. When a stockchaser needs to find the location of a part, he looks at the information generated by the previous night's midnight count which includes both inventory levels and locations for each part. The stockchaser then contacts a forklift driver by walkie-talkie and the forklift driver delivers the parts to the workstation in need. In the event that an assembly operator is running low on parts, he or she will grab the attention of either a forklift driver or a stockchaser when they drive by.

Problems with the current system. There are several opportunities to improve upon the existing material handling system. These inefficiencies can be divided into inaccuracies in the midnight count, drop zone layout problems, and information breakdowns.

Inaccuracies in the midnight count. While the midnight count is being performed, forklift drivers unload trucks and transport the material to drop zones. Forklift drivers temporarily leave material in drop zones or in aisleways, only to transport these parts to other drop zones at a later time. Because the midnight count takes several hours to perform and material is constantly being moved during this time, counters may overlook some parts and double-count others. The number of parts in partially full containers is also estimated, and there are some inherent inaccuracies in this method.

The results of the midnight count are a key informational tool used by stockchasers. However, this count is only a snapshot in time of the actual inventory levels and locations in the plant. The process cannot keep pace with the dynamics of an automobile assembly plant. This information is also used to adjust shipment schedules to the plant. The plant tracks the variance between the number of parts counted and the expected inventory levels based on shipments and usages for each part. Because of inaccuracies inherent in the midnight count, these variances are often very large.

Drop zone layout problems. There is no particular organization to the intermediate storage areas. Parts are stored in these areas in the order they are delivered to the plant. Parts do not have specific locations within the drop zones and pallets of material are placed in front of pallets of other parts. This method of storage results in stacks of parts which prohibit access to other components. When a certain part is needed for delivery to the line, a forklift driver may have to move several pallets of material to gain access to the needed material. The relocated pallets may later block access to other parts. These methods result in the multiple handling of many parts which wastes the time of the forklift drivers.

In the event that a drop zone becomes full, the parts assigned to that zone are dropped into a different intermediate storage area. Sometimes components are stored in empty spaces along the assembly line instead of in drop zones. These situations can result in the misplacement of parts which wastes the time of material handling personnel and stockchasers. One team member spent two hours with a material supervisor looking for a box of clips. If this box had not been found, it would have caused a production shutdown.

Information breakdowns. The difficulties discussed above can cause confusion on the part of forklift drivers and stockchasers when parts are misplaced or priorities are incorrectly set. In the event that stock levels run low without the stockchaser's knowledge, production workers must wait until a forklift driver or stockchaser travels by their station. Only then can an operator signal that he or she has a problem.

5.2 Description of the Proposed Material Handling Methods

The ultimate goal of the proposed material delivery system at WTAP is to pull material directly from supplier plants on an as-needed basis using a kanban system. It was felt that this would be too difficult a leap to make immediately; instead, an intermediate material pull system will be installed.

As a first step, the same method of scheduling supplier deliveries will be used, but the material will be unloaded from trucks and brought immediately to a different type of intermediate storage area -- a supermarket. A supermarket is nothing more than an organized drop zone, with a specific location set aside for each part. There will be five supermarkets dedicated to door line parts and these areas will be dispersed around the door line so that parts can be stored in the supermarket closest to their point of use on the line. The supermarkets will be installed in areas either currently used for drop zones or currently occupied by conveyors that will be removed in the process redesign.

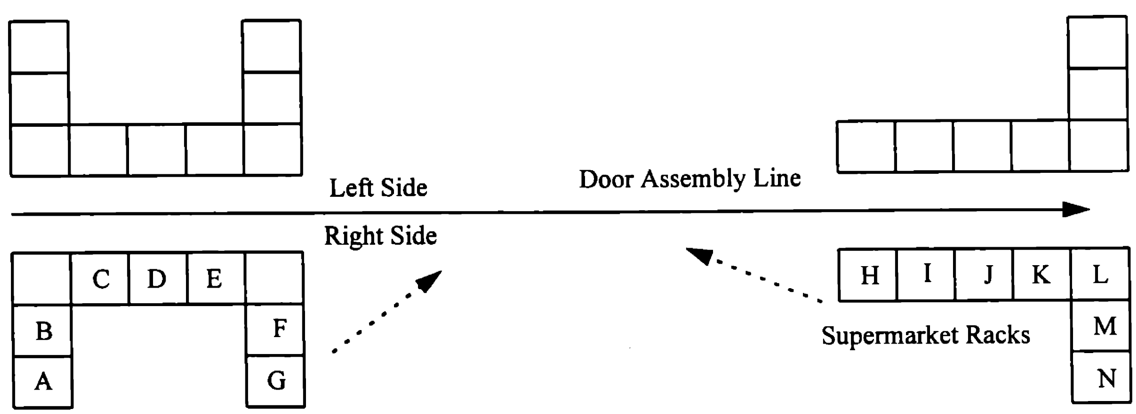


Figure 5.1: Example Supermarket Layout

An example of a supermarket layout is shown in Figure 5.1. Parts A through N are used on the right-hand side of the line; parts A through G will feed the upstream portion of the line and parts H through N will be used on the downstream section of the assembly line. Storage racks will be installed in the supermarket and each part will have a specific location in these racks. The most frequently needed parts will be placed closest to the line and lower use parts will be placed further away. In the example, parts F, G, and H are commonly used and parts A, L, and M are infrequently used. Each rack was designed to allow sufficient storage for the parts given the current delivery frequencies. Any part should be found in one of only three possible locations in the plant: at the unloading dock, in its roller rack on the assembly line, or in its rack at the proper supermarket. In addition to removing some inefficiencies noted in the existing process, supermarkets should meet the second material handling goal of facilitating inventory reduction efforts by allowing visual cues of inventory levels. The level of material in the supermarket can be monitored over time: if inventory levels are consistently high, delivery amounts can be reduced; if a part is overflowing its rack, it will signal that there is a problem in the system.

Kanban cards will be introduced on the door line and will allow operators to pull material from the supermarket to the assembly line when needed. Operators will be instructed to remove kanban cards from totes just prior to using the first part in that tote. The card will be placed in a chute attached to the roller rack which will direct the card toward the back of the rack. Material handlers will gather the cards on a pre-set schedule and use the cards to determine which parts to deliver to the workstations.

The proposed material handling system has the following advantages over the current process:

The performance of the midnight count for door line parts is simplified and the need for the count can eventually be eliminated altogether. As the new system will call for a few dedicated material handlers, some people performing the midnight count can be reassigned to the door area; without the need to track door parts, the number of people performing the midnight count can be reduced. The information gained from the midnight count should also be more accurate because there should only be three possible locations for any part.

The supermarket system is more organized. Because each part has a specific location that cannot be blocked by other parts, the new process eliminates double-handling by material handlers. The likelihood of a misplaced part is also greatly reduced because the location of each part is known.

The handling of information is simplified. Assembly operators no longer need to wait for a forklift driver to pass in order to signal the need for more parts. This is the purpose of the kanban system.

The system allows for a shift to JIT delivery. A small scale introduction of kanban cards will allow operators to get used to the system. After any learning barriers have been identified, kanban can be used plantwide and can eventually signal supplier deliveries instead of supermarket deliveries.

The new system does have one disadvantage: the amount of floor space dedicated to door parts storage will be greater than in the existing system. However, it is believed that the advantages outweigh this disadvantage, and the storage space can be reduced over time.

5.3 Implementation of the New Material Handling System

The first step towards moving to a new material handling system was convincing plant personnel that the current system had its faults. The team conducted several studies to support this argument, including one particularly powerful method. In response to the statement "91% of our parts are delivered just-in-time", the team spent two hours on three separate days over a one-week period counting the number of door parts in the plant. Data was separated into drop zone inventory and line storage inventory. The team averaged each day's count and the results are shown in Figure 5.2. The vertical axis displays the number of parts with inventory levels corresponding to the number of hours of inventory shown along the horizontal axis. The median total inventory level was 44 hours usage and the average was 79 hours of inventory. There are 16 production hours in a day. These histograms, probably more than any other single piece of information, convinced the plant production control department that the existing system of material delivery was inadequate.

Other studies included observing the movement of material within drop zones and the storage of material along the assembly line. The drop zone study consisted of mapping the contents of several drop zones twice daily for two weeks. Whenever new parts entered the drop zone, the time they appeared were marked on the material. The study showed that over time some parts moved within the drop zone and others remained in the drop zone for the entire two week period. The results were used to underscore the inefficiencies inherent in the existing material handling process. Once the plant was convinced that there may be better ways of handling material, the kanban and supermarket systems were designed.

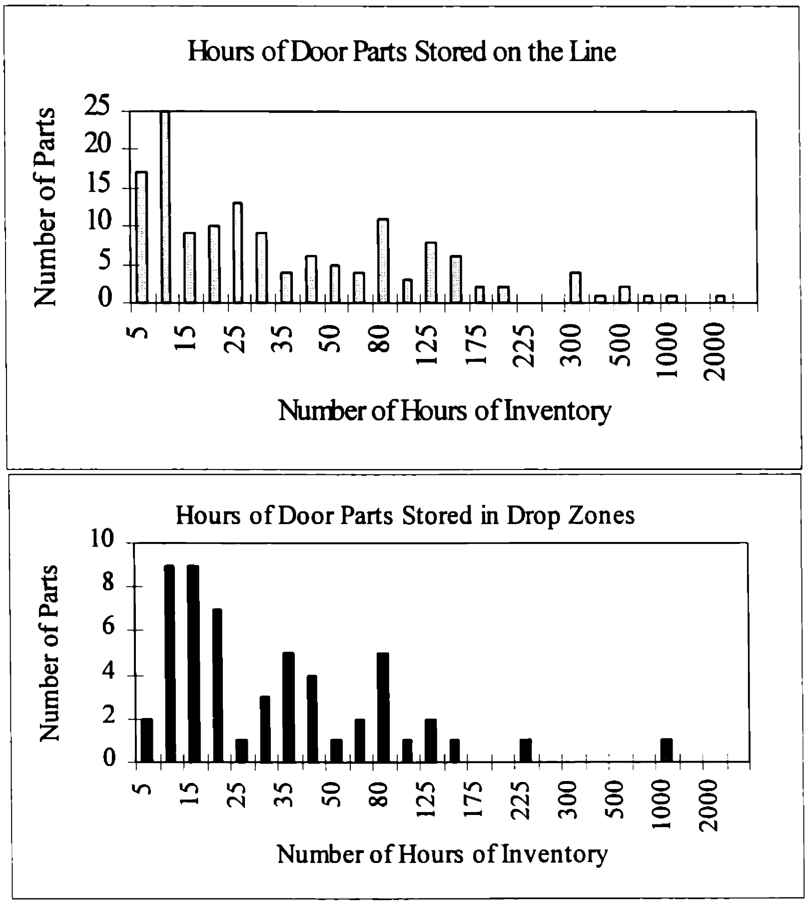


Figure 5.2: Inventory Level Histograms

Kanban cards. The number of kanban cards for each part could not be determined until both the part usage and number of parts per container were found. The current plant mix is 50 percent Rams and 50 percent Dakotas. In parallel with system installation, the plant will be shifting to a 25 percent Ram, 75 percent Dakota mix. Part usages for the Ram were calculated by dividing the existing usages in half. Part usages for the Dakota were found by scaling up the current usages and determining any significant changes due to the new model introduction. Once the number of parts per container were specified using the methods in Chapter 4, the number of kanban cards assigned to each part were calculated using the following formula [Monden, 1983; Nahmias, 1993]:

$$y = \frac{D * L * FOS}{a}$$

for a constant quantity withdrawal system, where:

y = number of kanban cards
D = average hourly demand
L = lead time in hours
FOS = factor of safety
a = container capacity

The lead time is the length of time between deliveries to the assembly line and the factor of safety was chosen as 1.2 to account for variations in hourly demand. The initial lead time, or frequency between kanban card collections by material handlers, was chosen as two hours. The team felt that two hours was a good starting point; this time window could be reduced as the plant gained experience with the system.

For an example kanban card calculation, consider power door latches for the Dakota. Seventy-five percent of the 60 trucks built each hour will be Dodge Dakotas and 70 percent of the Dakotas are expected to have power door locks. Therefore, the expected hourly demand for power door latches will be 32. There will be 20 latches in each tote. Therefore, the number of kanban cards needed for power latches will be:

$$y = \frac{32\, parts / hour * 2\, hours * 1.2}{20\, parts / tote} = 3.8 \approx 4 \text{ kanban cards}$$

These four cards will be in circulation between the workstation roller racks and the supermarket. When an operator selects a part from a full tote, the card will be removed from a plastic envelope on the front of the tote and sent down a chute. Material handling personnel will gather cards from the chutes every two hours and return to the supermarket to retrieve the needed parts. The material handlers will place each kanban card in a plastic envelope attached to the correct tote prior to loading the operator's roller rack.

Prior to full system installation which will occur in parallel with the doors-off process introduction, the plant will prototype kanban use on the existing line. Several workstations have been chosen to try kanban cards and any learnings that are gained from their use will be applied when the system is fully implemented on the door assembly line.

Supermarket system. Five areas adjacent to the door assembly line were chosen for supermarket installation. Because space is limited at WTAP, racks will be built in each supermarket in a pattern which maximizes the use of space in the area. For the initial layout, each rack was designed with enough capacity to handle the existing plant deliveries. The inventory levels are expected to be reduced over time, and the plant is currently experimenting with increased delivery frequencies of mixed load trailers for those suppliers located within 50 miles of the plant. The area set aside for supermarkets should be reduced over time as inventory levels decrease. Eventually, the plant could choose several parts from nearby suppliers and eliminate their use in the supermarket altogether. These parts could be pulled directly from the supplier plant to WTAP, with no intermediate storage in the supermarket. The learnings from these deliveries will be the first step towards operating a true JIT system.

All parts were divided into groups considering their ultimate locations along the assembly line. Parts delivered to common or adjacent workstations were all assigned to the supermarket closest to these workstations. Within the supermarket, the most frequently demanded containers -- or those with the greatest number of kanban cards -- were placed closest to the door line and less frequently used components were placed farthest from the line.

Summary

The new material handling system is a significant deviation from the current methods, although it is not so extreme a change as to cause major implementation blocks. The system is seen as an intermediate solution: it removes the inefficiencies inherent in the existing system, allows for inventory reductions, and is a step towards a true JIT system. As the plant gains experience with the system and inventory levels are reduced, the areas dedicated for supermarket usage can be reduced. Eventually, the plant could choose to remove several door parts from the supermarket and receive them JIT from the suppliers. Learnings from this process will aid in evolving to a true JIT system.

Chapter 6: Mistake Proofing Methods

The current product designs of the Dodge Dakota and Ram pickup trucks are very different. The trucks do not share any common door parts and the components look very different -- operators do not have any difficulty discerning between parts. The new model Dakota which will be introduced this year shares only two common door parts with the Ram pickup truck; however, there are many components that look almost identical between the two trucks and there are several parts that could be accidentally installed in the wrong vehicle.

Because the WTAP team became involved fairly late in the Dakota product design process, the flexibility to alter the design and facilitate mistake proofing was limited. The team was able to identify several systems which will aid operators and reduce the likelihood of assembly errors. This chapter presents the methodology used for this mistake proofing initiative and gives several examples of mistake proofing.

6.1 Mistake Proofing Methodology

The team considered the four basic concepts of Shingo's Zero QC system [Shingo, 1986] when designing the mistake proofing systems:

1. Use source inspections, that is, inspections for preventing defects and eliminating them entirely. Source inspections do not deal with the results of defect generation, they attempt to eliminate defects at their point of origin.

2. Always use 100 percent inspections rather than sampling inspections.

3. Minimize the time it takes to carry out corrective actions once defects are discovered. The best way to provide this capability would be to install a line stop, or andon system, along the door line to remove defects as soon as they occurred. This method would be preferable to the repair station system currently in place. However, for reasons discussed in Chapter 7, an andon line was not installed on the door assembly line.

4. Human workers are not infallible.

There are two types of mistake proofing regulatory functions, or methods: control methods and warning methods [Shingo, 1986]. Control methods halt operations when defects occur, thereby preventing the occurrence of multiple defects. Warning methods alert operators when abnormalities occur by energizing a light or alarm. Control methods are a more powerful means of preventing defects because they do not allow operations to continue once a defect occurs.

Ideally, the team would have liked to eliminate the possibility of incorrect component installation. One example of this concept would have been to design different hole patterns for parts to be installed in Ram and Dakota trucks. It would be impossible to fasten a Dakota part to a Ram door because the holes would not match. The team would also liked to have reduced parts complexity: there are 22 different wire harnesses, some of which are only installed once per month. Unfortunately, only a few minor changes were allowed in part designs and the team had to work within existing constraints.

A comparison study was performed by examining each Dakota and Ram part and asking the following questions: "Could an incorrect part accidentally be installed?" and "Could an operator accidentally choose the wrong part, only to find he or she had selected the incorrect part upon installation attempt?". Each component was examined and assigned to a point along the spectrum shown in Figure 6.1. The highest priority parts were those that could be accidentally installed in the wrong vehicle. Among this group, the items were ranked according to the severity of impact if a mistake were made. The second highest priority group were those parts which could be selected incorrectly. The operator would realize this mistake when he or she attempted to install the part into the door. However, time would be wasted as the operator returned to select the right component. Lastly, little or no attention was paid to those items which were either common or easily differentiated between the two trucks. The next section provides several examples of parts falling into each category.

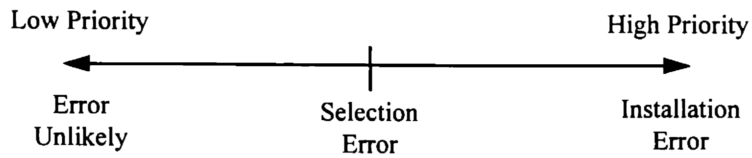


Figure 6.1: Prioritization Spectrum for Mistake Proofing Efforts

6.2 Mistake Proofing Examples

Potential installation errors. The highest priority item was the door wire harness. The operator installing harnesses into the right-hand door has a choice of 14 different wire harnesses. These choices are dependent on the type of truck and the option content of the vehicle, that is, whether the truck has electric mirrors, power or manual windows, or high-end or low-end speakers. The wire harness is the first component installed into the door and an incorrect installation can cause mistakes in downstream processes.

To determine the correct wire harness to install, the operator currently looks at the build sheet -- which is a sheet of paper taped to the door and lists all options to be installed -- and finds the part number corresponding to the needed wire harness. In theory, at downstream workstations each operator should observe either the build sheet or a computer terminal at his or her station to determine which components to select for assembly. In reality, many operators look at the connections on the installed wire harness to choose their parts. For example, an operator who installs window regulators looks at the wire harness and installs a power regulator if the harness has a connection for the regulator or installs a manual regulator if the harness has no connection. There is no double-check in downstream processes to ensure the correct harness has been installed and incorrect wire installations cause the incorrect assembly of downstream components.

For these reasons, the wire harness was targeted as the highest priority item in the mistake proofing process. A warning method will be used to alert the operator when an incorrect part is selected. Each wire harness will be presented to the production operator in totes placed on roller racks. Each separate wire harness has a pre-assigned spot in the roller rack and an infrared light bar, or light screen, is mounted above each location. The light bar directs infrared light down from the bar to the front, top edge of the tote. When an operator reaches his or her hand into the tote to select a part, the light screen is broken and a signal is sent to the workstation computer.

Each light bar has a green light and a red light mounted on its front. When a door enters the workstation, a signal is sent from the workstation computer to the light bar above the correct part and that green light is energized. The operator notices the green light and selects a wire harness from that tote. When the light screen is broken, the computer resets and waits for the next door to enter the station. If instead of reaching into the correct tote, the operator selects a part from a different tote, the red light on that bar is energized and a warning buzzer sounds. The green light above the correct tote flashes, and when the operator breaks the light screen for the correct part, the system resets.

The operator at the wire harness station installs almost 500 harnesses each day. Being human, this person is bound to make an occasional mistake. The light screen system is not being installed to de-humanize this person in any way; rather, the system is meant as an aid to the operator to improve the quality of the product he or she is helping to produce. The mistake proofing system must be explained to the person in this manner.

Another example of a mistake proofing method for potential installation errors can be explained using the window regulators as an example. The window regulators for Dakota and Ram trucks are almost identical in appearance, and a Ram regulator could be accidentally assembled to a Dakota door and vise versa. By the time this problem was identified by the plant team, it was too late to perform any major product re-designs. However, the team was able to recommend a last-minute tooling change for minimal cost. The word "RAM" will be stamped on Ram window regulators and will aid operators in selecting the correct part.

Potential selection errors. Selection errors are not as detrimental as installation errors because defects cannot be passed through to the intermediate or end customer. However, selection errors waste the time of assembly operators. If an operator selects the wrong part he or she will discover an error has been made when part assembly is attempted because the part will not fit the door. The team decided to eliminate selection errors through the use of color coding and symbology.

As an example, the outside door handles for the Ram and Dakota are almost identical, but the Ram handle is held with three fasteners and the Dakota handle is assembled with only two fasteners. Each workstation on the door assembly line will be equipped with a color computer monitor. This monitor will display the part number and description for every option for which the station is responsible. Part numbers can be displayed in different colors on the monitor which correspond to the tags mounted below every tote on the roller racks. Considering the handle example, the part number and description for the Ram handle can be printed on a blue tag and attached to the correct spot in the roller rack. The same information for the Dakota door handle can be printed on a yellow tag. When a Dakota door enters the workstation, the computer monitor will display the part information in yellow. Similarly, the information for Ram doors can be displayed in blue. To aid color-blind operators, a triangle could be printed on the tag and screen for Dakota doors and a square could be used to code Ram parts.

Summary

For a manufacturing plant that assembles two or more entirely different products on the same line, mistake proofing must be considered across product platforms. Manufacturing personnel should be introduced to the process at the earliest possible time so their ideas can be considered and their impact can be maximized. Mistake proofing efforts at WTAP were prioritized based on the potential for installation and selection errors. Again, the purpose of these systems is to aid people who perform the same tasks repetitively. The mistake proofing systems are not meant to de-humanize operators, only to help them perform their jobs better.

Chapter 7: Organizational Culture and Change

The methods described in the preceding sections are improvements over the current manufacturing processes used at WTAP. Work along the assembly line is more balanced and the effects of variation upon line operations are mitigated. The material handling and display methods will improve productivity and reduce confusion. Mistake proofing methods should reduce assembly errors. However, lean manufacturing is an entire system and the introduction of these methods alone will not allow WTAP to become a world-class manufacturing facility.

The processes that will be introduced on the door assembly line must continually evolve and these improved methods should be introduced to the rest of the plant. In order for this dynamic process to occur, the organization of WTAP must change to support lean manufacturing. The most significant barrier to change at WTAP is the existing culture. This chapter examines the plant culture and provides recommendations the plant should follow to implement lean manufacturing.

7.1 Description of the Organizational Culture

The organizational culture at WTAP will be described using Schein's cultural analysis [Schein, 1992]. Schein defines culture as "a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems." Schein also distinguishes between three levels of culture: artifacts, espoused values, and basic underlying assumptions. Artifacts are those phenomena that an outsider readily observes when introduced to a new culture. Examples of artifacts include the group's language, physical environment, technology and products. Espoused values are the verbalized philosophies and goals of the group and can predict what people will *say* in a given situation, but not necessarily what they will *do*. The third level of culture, basic underlying assumptions, are unconscious, taken-for-granted beliefs, or mental models

[Senge, 1990], that the group has learned together over its history. These beliefs have become so ingrained in individuals that their validity is not even questioned. Schein explains that "any challenge to or questioning of a basic assumption will release anxiety and defensiveness."

Artifacts. The plant was built in the 1930's and is not laid out optimally for the complex process of building two entirely different vehicles on the same assembly line. The workforce is a traditional union organization with many specific job classifications and an average seniority of close to 30 years in the plant. Until recently, the plant did not hire any new operators into the workforce. In fact, operators fall into one of two age groups: the majority of people have close to 30 years experience in the plant; there is a small group of young people that have been hired into the plant within the last few years. Seniority is the determining factor in job assignments [UAW, 1993].

Espoused values. The most frequently heard espoused value is the importance of quality. In fact, without any major organizational or process changes, WTAP was recognized as the most improved North American Light Truck plant in 1995 with a 44 percent reduction in reported problems [JD Power, 1995]. While some of this improvement can be attributed to the plant moving down a learning curve one year after introducing a new model of the Ram truck, much of the improvement is due to an increased attention to quality. The management at WTAP stresses quality and this attitude has been internalized by the workforce because of several outside factors. First, the workforce has seen several jobs outsourced over the last few years. Also, the Ram truck is built at several other plants, including two in Mexico. The threat of foreign competition for jobs has driven the need for higher quality production. Lastly, the workforce is very aware of the productivity and quality of the competition's trucks, particularly Japanese producers.

Basic underlying assumptions. One basic underlying assumption of the plant culture is that seniority is and should be the determining factor in job assignments. The most senior people are assigned to the preferred jobs; the most physically demanding and difficult jobs along the assembly line are all assigned to junior personnel. People do not rotate between jobs: senior operators have worked long and hard to get to their positions and have no desire to rotate to more difficult jobs. However, there are several people who rotate through different jobs and act as reliefs for other operators. These people all tend to be recent hires and enjoy the variety and challenges that come with performing different jobs.

Another basic assumption of the culture is a mistrust of the "program of the month" and a reluctance to change. In the mid-1980's the plant organized the entire workforce into teams. However, the workforce was given no training or tools to work in this environment and management did not put a supportive infrastructure in place. The team structure failed. When the use of teams was mentioned to one operator, he said "we tried that once before and it didn't work. Team is a dirty word around here."

There is an initial reluctance to try new methods, but if the advantages of the methods can be proved, the workforce is more than willing to try new ideas. As an example, two members of the team brought a roller rack to a workstation and asked the operator at that station if she would be willing to try the new rack and give feedback on its performance. She became very defensive and explained that she liked her workstation "just the way it is." When team members tried to explain the advantages of the rack, she became adamant and alerted a union steward who came to the scene. The team explained the advantages of the rack to the union steward and asked if they could just set up the rack and leave it at her station. If she chose to, the operator did not have to use the rack. The operator and steward discussed the situation and agreed that the team could leave the rack, just as long as the woman "didn't have to use it if she didn't want to." The team returned to the scene later in the day and the woman had tried the system and had nothing but praise for the new method. A number of people passed by the station with questions and each had asked if they could also try the rack.

Younger members of the workforce tend to be more open to change because they have not been immersed in the culture for as long as older members. An attempt to prototype the use of kanban cards was greeted with disdain by some senior workers, one of whom said "my job is to assemble parts to the truck, not to have to deal with these cards. It's extra work." A junior person who tried the same system said "This is great! You mean I'll never run out of stock again?" This is not to say that all senior workers are resistant to change -- there are a large number of older operators who embrace change because they understand that one purpose of these methods is to improve vehicle quality.

Actually, all workers were more than willing to give feedback to improve assembly operations. While trying to design the new workstations for the doors-off line, team members asked each operator performing assembly operations to the door "what would you do to change your workstation if you could start from scratch?" Every worker had ideas for improvement, many of which were implemented on the new doors-off line.

There is added resistance to ideas that are not originated in the plant. To minimize this "not invented here" attitude [Shiba, 1993], the in-plant supermarket will be called a Central Material storage Area, or CMA and kanban cards will be referred to as a Material Pull Cards, or MPCs. Brackets on the first prototype roller racks used in the plant were stamped with the words "Made in Japan." Operators became extremely upset at this and an American supplier plant was found to supply the roller racks.

The implementation of new production processes is facilitated when performed in parallel with a new product launch. Plant personnel tend to equate changing processes with the product launch. Upon seeing a roller rack system for the first time, one operator said "oh, so this is something new that we are doing for the '96 Dakota."

Although many members of the workforce are initially suspicious of new ideas, prototypes of new production tools have eventually had positive results. Operators are willing to try new ideas once the benefits of these ideas have been explained. The challenge of introducing change to the organization and giving operators the tools to implement change themselves lies with plant management.

7.2 Breaking Down the Organizational Barriers

In order to fully implement lean manufacturing methods at WTAP, the organization must support its initial introduction and work to continually improve the system over time. Hayes and Pisano [1994] argue that manufacturing improvement programs should not be thought of as *ends* in themselves, but should be thought of in terms of the capabilities they add to the organization and the ability they provide to think differently about solutions to problems. In a dynamic setting, these programs should be viewed as part of a longer term path of improvement and a set of skills that will allow the organization to open up new opportunities. The methods implemented on the door assembly line are not meant to simply solve existing problems, they should also give the plant tools which will allow it to meet future challenges. One of the core capabilities of the lean manufacturing system is the ability of those closest to the process to improve the system through teamwork.

Changing a culture that has roots as deep as those at WTAP will not be easy. However, there has never been a better time to change the culture than the present. The workforce understands the importance of quality. Younger operators are willing to change, as are many senior workers. And those senior members that are not willing to change are reaching retirement age. In fact, the automobile industry is about to go through one of the most dramatic turnovers -- and has one of its greatest opportunities to change -- in its history: within the next few years, 200,000 new workers will be hired into the U.S. auto industry, providing it with a higher percentage of new workers than at any other time in its history [Detroit News, 1995]. By organizing the workforce into teams now, management can begin to put in place the culture it wishes for new hires to step into within the next few years.

In his analysis of JIT work teams in both union and non-union environments, Waldo [1991] found there were four essential characteristics of successful implementation programs:

Commitment from management. Both corporate and plant management must support a team structure. At WTAP, union leadership and management will have to work together to implement teams. Waldo also cites that, while there may be initial gains, full implementation can take from six months to a year and a half. Along with commitment, plant leadership must maintain open communication with production workers to minimize resistance.

New supervisory skills. Supervisors cannot lead through "command and control" methods. Instead, supervisors must learn to be coaches and facilitators. Supervisors also must gain the skills to act as the providers of information and resources. Feedback must be given to teams to allow their performance to improve over time.

Continuous improvement philosophy. Successful teams are those that foster a pursuit of continuous improvement in their jobs

Team members take new roles. Teams are self-managed and have an increased say in plant operations and the offering of improvement suggestions. Management must provide workers with both initial and follow-up training to teach these new skills. Waldo offers some statistics from the teams he studied. Seventy-seven percent of team members found their jobs more satisfying than their previous job, while six percent did not. Eighty-one percent said they found their new positions more challenging than their previous jobs, while six percent did not. Finally, 48 percent of workers said they were more anxious in their new positions, while 27 percent were not. Anxieties were greatest at the introduction of the team and reduced over time.

The door assembly line offers the opportunity to introduce a team structure to the plant in parallel with the introduction of a new manufacturing process. A small scale introduction will allow management to concentrate its resources on a limited area without risking the disruption to production that could potentially occur with a plant-wide introduction. In fact, the existing union contract allows for production workers that are essentially team leaders. A plant Production Specialist has the following duties outlined in his or her job description: train new operators, relieve operators, provide problem solving, coordinate defect reduction efforts, and perform SPC data gathering and charting. However, Production Specialists are currently assigned to groups of approximately 30 people. In order to be effective, a team leader should support a group of four to eight people [Mishina, 1992; Toyota Georgetown Visit].

The need for discipline in lean production processes was discussed in Chapter 4. This discipline can be provided by teams that are aware of the impact each individual can have on the production process and work to continuously improve their environment.

Without a team structure in place, there are two aspects of the Toyota Production System that are not being implemented on the pilot project: an andon line and standardized work procedures.

Andon line. As explained in Chapter 2, an andon line allows operators to stop the production line and repair problems immediately instead of allowing defective components to travel to downstream processes. The process involves team leaders and discussions among team members to ensure problems do not reoccur. Because the use of a line stop mechanism requires the support of teams, an andon line will not be installed on the door assembly line. Instead, the defects in the process will be removed by operators at repair stations.

This is not to say the opportunity to install an andon line has passed. There is a 20-minute door buffer between the door line and the main assembly line, which allows the door line to be stopped for 20 minutes without affecting the main line. An andon line could eventually be installed and workers at repair stations could act as team leaders.

Standardized work procedures. Standardized work procedures give team members the tools to improve the productivity and reduce the variability in their jobs. These refinements can lead to a series of interconnected improvements [Adler, 1993] including:

1. Improved safety and reduced injuries because workers examine sources of danger and strain.

2. Increased quality standards because those most familiar with the work identify effective procedures.

3. More efficient and equitable job rotations.

4. Increased plant flexibility to changing demand. Workers and industrial engineers can work in parallel to redesign work layouts. For example, NUMMI [Adler, 1993] can convert to new line speeds in four to six weeks, a process that would

have taken the GM organization previously inhabiting the plant six months to a year. NUMMI can accommodate decreasing demand without laying off production workers.

5. Increased job satisfaction because workers have input to the design of their jobs instead of having to implement changes recommended by industrial engineers.

Without a team structure in place, the use of standardized work procedures is not possible. Once a team organization is introduced to WTAP, workers can receive training in standardized work

Summary

The production tools discussed in previous chapters will improve plant operations, but far greater improvements will be possible by involving production workers in the manufacturing process. The introduction of a team structure to the plant will give it the flexibility and capability to meet future challenges. There are four characteristics of successful team implementation: commitment from plant and corporate leadership, fostering a continuous improvement environment, and the teaching of new skills to supervisors and team members. With the introduction of teams to the workforce, a full implementation of lean production methods can be realized, including the installation of an andon line and the use of standardized work procedures.

Chapter 8: Conclusions

8.1 Research Findings

This research effort demonstrated a method to implement lean manufacturing concepts to a traditional mass production assembly plant. The proposed system is an intermediate step which will familiarize the plant with TPS techniques and can eventually be expanded and built upon to convert to a true lean production system. Other results of this research effort are:

Small scale introduction minimizes risk. Initial introduction of new production methods to a limited area of the plant minimizes the risk of production disruptions and allows the plant to learn new procedures on a small scale. Additionally, methods can be prototyped at single, existing workstations prior to their debut on pilot projects.

Improvements can be realized with an intermediate system. The system which will be introduced to the pilot line will be an improvement over the existing plant processes. Savings over the existing system are difficult to estimate. Assuming annual labor costs of $100,000 per person including overtime and benefits, $800,000 in annual productivity improvements can be realized. Also, it is estimated that the use of an in-plant supermarket can eliminate $15,000 in inventory carrying costs. Finally, error reduction techniques should improve quality, but this improvement is difficult to measure. Given these improvements, this system will still not realize the full benefits of a truly lean system. The main learnings from each subsystem follow:

<u>Workstation Layout:</u> Line balancing can result in significant productivity improvements. Also, for assembly lines building multiple products, balancing the work content across products minimizes the impact of scheduling variations. Productivity can be improved further by reordering tasks to eliminate non-value added activities.

Material Handling and Display: A material display system using totes and roller racks increases the density of parts storage. This practice can improve productivity and operator comfort while reducing line inventory and the potential for installation errors. Parts will be pulled to the line from an intermediate supermarket. This system will aid in inventory reduction while reducing confusion. Practice with these methods and continuous improvement of the system will allow for a shift to full JIT production.

Mistake Proofing: Plants producing multiple products on the same assembly line should consider mistake proofing and must involve manufacturing personnel early in the design process. Resources can be focused initially on those parts which could be incorrectly installed, followed by parts selection problems.

Significant organizational change will have to occur to realize the full potential of lean production. The introduction of an andon line and standardized work procedures could not be supported without a team structure in place. More importantly, production personnel are the most familiar with the assembly process and should be organized into teams to continuously improve the quality, productivity, and working environment of the plant.

Management and union leadership must commit to lean production and train supervisors and production workers to thrive in this environment. The real barriers to a full introduction of lean production methods are organizational. Only through the efforts of management and union leadership can these barriers be removed. A team-based organization should not be looked upon solely as a means to support lean production; teams give workers new capabilities to solve difficult problems and can support the organization in pursuing future opportunities.

8.2 Recommendations for Future Work

Develop key metrics to measure improvements in the pilot line. Key metrics can be used to measure the improvements in the door line as workers learn the new system. These metrics can also be used to measure the performance of other areas of the plant, as lean production methods are implemented elsewhere. Management can learn what works best in implementation efforts by continually measuring the performance of the systems.

Benchmark other efforts to implement teams in traditional union shops. Organizational change is the most critical component of lean production implementation. Understanding how other union plants have introduced teams will facilitate the launch of a team structure at plants wishing to shift to new production processes.

Examine the feasibility of implementing lean methods on similar lines when introducing at multiple plants. For those companies with similar operations at multiple plants, choosing similar pilot projects may aid lean production implementation. If other plants in the Chrysler Corporation had used their door lines as pilot projects, it would have simplified the tote assignments for parts that were common across plants. It would also facilitate cross-plant benchmarking and learning.

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