

**Optimizing the Sequenced Production Schedule by  
Managing the Internal Supply Chain**

By

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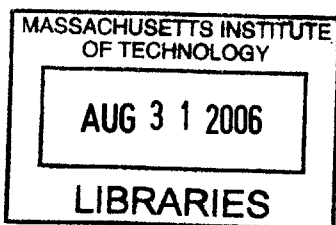
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**BARKER**

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Aimee L. Vessell

Submitted to the Sloan School of Management and Department of Environmental & Civil Engineering on May 12, 2006 in partial fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Civil and Environmental Engineering

## Abstract

Many manufacturing companies wrestle with managing in-house manufactured inventories especially in the climate of Just-in-Time (JIT) manufacturing and with constant pressure to reduce inventory levels. One popular self-managing approach to controlling inventory levels while being responsive to customer demand is implementing a 'Pull' system. A Pull system is one that takes production signals from the downstream process and is based on true customer demand. This is in contrast to a 'Push' system that takes the production signal from the upstream schedule.

This thesis will explore inventory management strategies at 3WA Powertrain Operation (PTO) as they approach plant wide implementation of 'Pull-to-Assembly'. 3WA PTO is working to completely link each of their in-house component (parts) production processes to the scheduled Assembly process such that component production signals will each 'pull' from the following process step and ultimately from the Powertrain Assembly schedule.

*The tested hypotheses include:*

- 1) For 'Pull-to-Assembly' to be successful, a highly synchronized and visible in-house inventory management structure must first be in-place. Successful inventory management requires that inventory levels for each component must be completely understood and tuned to the variety of the component, process lead time, demand and variability in both lead time and demand.
- 2) A Pull system, like any other manufacturing process or technology, requires effective integration of the human, organizational, and technical system features.
- 3) Transitioning from a primarily Push to a Pull system as well as implementing new inventory strategies requires effective management of change.

This thesis leads with the analysis of technical features required to implement a Pull system at 3WA as well as to improve in-house inventory management methods. Included within this technical analysis is the presentation of a 'calculator' tool that allows the user to determine initial inventory levels appropriate for a given part based on the demand/lead time scenario. Following the more technical analysis, this thesis examines the organizational change and human elements needed to transition to and sustain a Pull system in this organization.

The following overarching conclusions were developed based on observations, research and experimentation at 3WA PTO. More specific conclusions related to the topics of 'Pull-to-Assembly, inventory management, data driven decision making, 'pulling' change in a tribal knowledge culture and the "demographic cliff" are presented within the thesis.

**Standardized processes and system stability along with accurate, knowledgeable and visible inventory management** must be in-place before an extensive 'Pull' system will be successful.

**There is no ‘one-size fits all’ for inventory management.** Inventory management depends primarily on expected demand, lead time and the variability in both. Equally important to choosing an inventory strategy, however, is having a solid understanding of true customer needs including how they will signal demand, how often and how fast the product is needed.

**Change must be ‘Pulled’ from an organization for ‘True Change’ to happen.**

**The ‘demographic cliff’ is approaching** for many traditional manufacturing companies like 3WA and the right employee skills profiling, retirement policies, and knowledge retention/sharing strategies must be in place for both short-term and long-term company success.

Thesis Supervisor: Thomas A. Kochan  
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## Acknowledgements

Thank you...whoever you are...you have reached Page 5....I hope you enjoy the rest. Although it will be tempting to skip to the last Chapter, I encourage you...in fact, I challenge you to read from beginning to end.

For me this will be the toughest piece of writing in this thesis. How do I thank everyone without forgetting anyone? I imagine it will be quite impossible. To truly thank everyone who has helped me reach this point in my life would require another thesis length. For those I know well and even those whom I have only encountered briefly, please take a moment to think about the last time we spent together. My hope is that you are now smiling, or better yet, laughing too. Consider that my personalized thank you because I'm sure I'm about to forget someone important.

To my Mom and Dad who are impressed enough by my accomplishments to be proud, but not so much that they let me forget how to be humble for all my blessings. You know how much I love you both and words are just not enough.

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My farewell to MIT-LFM is a poem I have used as a personal credo before I arrived in June 2004 and will strive to continue to live by as I continue through to my next adventures. I hope you recognize some of these things in me and choose to adopt some for yourself...

Thanks everyone...on to the next...

## I'd Pick More Daisies

By *Nadine Stair, age 85*

If I had my life to live over, I'd try to make more mistakes next time.  
I would relax. I would limber up.  
I would be sillier than I have on this trip.  
I would be crazier. I would be less hygienic.  
I would take more chances, I would take more trips.  
I would climb more mountains, swim more rivers, and watch more sunsets.  
I would burn more gasoline. I would eat more ice cream and less beans.  
I would have more actual troubles and fewer imaginary ones.  
You see, I am one of those people who lives prophylactic ally and sensibly and sanely, hour after hour, day after day.

Oh, I have had my moments.  
And if I had it to do over again, I'd have more of them.  
In fact, I'd try to have nothing else.  
Just moments, one after another.  
Instead of living so many years ahead each day.  
I have been one of those people who never go anywhere without a thermometer, a hot water bottle, a gargle, a raincoat, and a parachute.

If I had to do it over again, I would go places and do things.  
I'd travel lighter than I have.  
If I had my life to live over, I would start barefooted earlier in the spring and stay that way later in the fall.  
I would play hooky more. I wouldn't make such good grades except by accident.  
I would ride on merry-go-rounds.  
[I would ride on motorcycles].  
I'd pick more daisies!

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# 1 Introduction

This thesis is based on my research at a major manufacturer of recreational vehicles and powertrains headquartered in the Midwest United States. Research and observations were predominantly performed at one of the manufacturer's powertrain plants and so reference to the project location will herein be referred to as "3WA Powertrain Operations". Note that previous Leaders for Manufacturing (LFM) theses have referred to this company as "Company A", "Company D", and "Mighty Motors". I have chosen an alternate moniker so as to distinguish this project which took place at a unique location from the previous projects.

## 1.1 Company Overview

The source of the name 3WA stems from the founders of the company (William, Arthur, Walter and William). In 1903, two friends William and Arthur built the first product in a wooden shed. Soon after, two brothers of Arthur, Walter and William, joined the team and all worked together to build the first 28-foot x 30-foot factory. Today, the company is an established leader in their market with a dominant market share and strong culture evident in employees and customers alike. The company enjoys more than a one-hundred year history and prides itself on delivering a world class, high quality product to an enthusiastic market.

### Circa Spring 1912



**FIGURE 1-1 – Photo of founders of the company**

3WA has over 9,000 employees worldwide and has recorded record revenues and earnings for the last 20 years. In 2005, 3WA reported \$5.3 billion revenue with over 18 percent profit. For the 2006 model year, 3WA expects to manufacture 329,000 product units. To create growth in their industry, they have focused heavily on quality and production capabilities as well building a culture of continuous improvement and operational excellence.

## **1.2 3WA Powertrain Operations (PTO) Overview**

The 3WA Powertrain Operation (PTO) manages component production and assembly for three families of powertrains. Both component production and assembly run on a planned work week of three (3) shifts per day and five (5) days per week. Currently, there are over 75 combinations of powertrain units (mated engine and transmission) that must be delivered to customers (3WA Final Vehicle Assembly plants) in a specific sequence delivered by truck.

The Powertrain Assembly line runs based on a sequenced schedule known up to three weeks in advance. Despite this advanced information, there are occasions when sequenced units are taken out of the schedule; when this happens, the unit is said to be 'Cut' from the schedule. The primary reason a unit will be Cut from the schedule is temporary shortage of a part(s). The assembly process on any given unit will not begin until all parts needed for that unit are available. This is important both for Assembly process and quality control. Many parts are supplied by an outside supplier, but the majority of key components are machined and processed in-house by four (4) component groups: Transmission, Uppers, Lower, and Powdercoat.

Each component group is responsible for managing their own finished parts inventory that feeds the Powertrain Assembly line. Processing lead times (raw part to finished part) for in-house produced parts range from 45 minutes to over 12 hours. Because the sequenced Assembly schedule is known in advance, many component groups look ahead to the upcoming production schedules to plan their production. The component groups with longer lead time parts tend to look further out in the schedule to anticipate what they will need a shift or more later. Whereas other component groups with shorter lead times may be looking at the upcoming schedule only hours later. Basing production off the future schedule is problematic for everyone when there are deviations from the planned schedule.

Schedule deviations are most problematic for longer lead time components because the processing times are too long to respond to short term schedule changes. If units are being assembled that were not in the original schedule, the Assembly line may be consuming more of a part than expected and the replenishment time from the component areas is likely longer than the time it will take for Assembly to consume the parts; this would lead to parts shortages and possibly more schedule Cuts. Even component groups with shorter lead times can experience problems from schedule deviations, especially if changeover times from one part to another are significant relative to the Assembly consumption rate. In addition, short lead time component Managers often find themselves in reactive mode trying to keep up with the bullwhip effect that schedule deviations send through the plant.

## **1.3 3WA PTO Workforce and Organizational Culture**

The 3WA PTO workforce is comprised of both salaried and hourly (Union) staff. Salaried staff include, but are not limited to Plant Managers, Area Supervisors, Materials Managers, Finance Analysts, engineers, and administrative personnel who reside primarily in the office area with occasional trips out to the factory floor (e.g., engineers). Hourly, Union staff primarily reside on the factory floor and, in general, do not maintain offices/desks in the office area except for the Union leadership who has a large Union office within the main office area. Hourly staff include, but are not limited to machine operators, Assembly staff and skilled-trades. The relationship between the salaried management and the Union is characterized by 3WA as a Partnership and, for the most part, this relationship is amicable and cooperative.

Out of the long history and continued growth of 3WA, a tribal knowledge and relationship-based culture has emerged. In addition, despite typical struggles early in the company history, recent continued

company success has created a bit of a ‘fat and happy’ scenario in which a crisis is needed to convince people change should happen. As my company Supervisor warned early in the project:

*“The only way things ‘get done’ around here that will give people the incentive to change is if there is a crisis or what we like to call a ‘significant event’. For example, we got ISO certified in 2 years...it takes most companies 5 years. Why did that happen? People were told that unless we were ISO certified in 2 years, we wouldn’t be able to sell product in Europe.”*

Others around me observed that there is a need for better accountability, more formal lines of communication, and better problem solving systems that are not necessarily encouraged by a highly relationship-based culture. The following quotes from 3WA PTO staff (both salary and hourly) illustrate this point:

*“Things won’t change until there is better accountability.”*

*“There are not enough formal lines of communication. Most of the communication that happens on the floor is between informal lines of communication/relationships that have developed over time. However this creates an imbalance where information is not visible to everyone in the same way.”*

*“We don’t have problem solving measures/guidelines in place. We’re just reacting to the fires.”*

In addition to the challenge of implementing change in a tribal knowledge, tradition driven culture, 3WA is also confronting possible repercussions from an aging workforce – the ‘demographic cliff’. As both salaried and hourly staff approach retirement age, there is the threat that much of the tribal knowledge will walk right out the door with them.

## **1.4 Project Introduction and Evolution**

3WA PTO recognized the potential problems that schedule deviations posed to component production groups. In addition, they were interested in exploring methods to minimize both in-process and finished goods inventories. Finished goods inventories are finished parts that are staged at the end of the component process and as close to their consumption point at Assembly as possible. It is important to note that most component production processes are laid out on the floor such that the finished parts exit the production process at or near the point of Assembly consumption. This layout reduces the amount of parts movement needed to get parts from finished goods to Assembly.

One frequent solution to controlling inventory levels while being responsive to the downstream customer demand is to implement a ‘Pull’ system. A Pull system is one that takes production signals from the downstream process and is based on true customer demand. This is in contrast to a ‘Push’ system that takes the production signal from the upstream schedule. Both Pull and Push systems will be discussed in more detail in **Chapter 2**. Upon my arrival, 3WA PTO was in the early stages of implementing a Pull system throughout the plant; their implementation was called ‘Pull-to-Assembly’.

Therefore, my initial project was to assist with the implementation of ‘Pull-to-Assembly’ throughout the plant. In addition, because 3WA PTO recognized that schedule deviations were straining their in-house production processes, they also wanted to know: “Why do we have Cuts?” (translation – What is causing schedule deviations? You may recall that a Cut is a unit that is temporarily removed from the production schedule most often because one or more parts are not available at the time the unit comes up in the schedule). To understand what causes these (Cuts) and other deviations from the schedule, I developed a

high level of understanding of the sequencing/scheduling system and how the schedule and schedule deviations were communicated to the plant. This is discussed in **Chapter 3**.

In the process of working on these three project aspects (Pull-to-Assembly, schedule deviations and sequencing/scheduling), I realized that unstable inventory management practices and a lack of visibility in both the scheduling and in-house inventory management systems were prohibiting both the success of the Pull-to-Assembly implementation as well as being the leading cause for deviations in the schedule. This conclusion led me to investigate inventory management strategies that would bring enough stability to the system to enable both reduction/elimination of Cuts as well as a plant-wide Pull-to-Assembly implementation (see **Chapters 4** through **6**).

While investigating the many facets of my project, I recognized that along with some of the technical challenges facing 3WA PTO, there were also several strategic and organizational/cultural challenges facing them both in terms of operations growth and implementation of 'new' inventory management strategies (e.g., Pull). Some of the future strategic challenges facing 3WA PTO as well as my observations on organizational change challenges, such as the demographic cliff, are discussed in **Chapter 7** and **Chapter 8**, respectively.

Finally, my overall conclusions are summarized in **Chapter 9**.

## **1.5 Research Methods**

My overall research methods included collaboration of on-site data collection, observation, interview, experimentation and outside research. In terms of data collection, the following information was collected for the duration of the project from mid-June to the end of December 2005:

- Finish goods (supermarket) levels (numbers of parts) for all in-house produced components for each of three (3) shifts during the planned five (5) day work week
- Number of Cuts per shift
- Root causes of all Cuts (especially those attributed to in-house production parts)
- Scheduled daily assembly run vs. actual daily assembly run (to identify schedule deviation)
- Total number of powertrain models and general frequency of occurrence in daily schedule
- Total material and conversion cost of each in-house produced part
- Total units produced per shift, per day
- Per shift absenteeism for planned five (5) day work week

In addition, over the course of the project, I spent an average of 30 percent of my day on the factory floor interviewing people involved in the processes applicable to my project as well as performing general observation of these processes in order to reconcile the information collected during interviews with what was actually happening on the floor. In the most intense period of observation and interviewing, I spent three full days with the third shift sequencing team understanding the sequencing process and the circumstances that tended to hold up the truck loading sequence (this will be explained in Chapter 3). A general list of people who were interviewed at least once, and most on multiple occasions includes:

- Plant General Manager
- Plant Product Manager – Assembly
- Plant Product Manager – Component Groups
- Lead Scheduler
- Plant Supply Chain Manager
- Two Sequencers on each of the three (3) shifts (those who sequence units for the trucks)
- Process Leads for each Component Group (overseer of overall operations of that group)



- Supervisors from each Component Group (each Component Group will have multiple Supervisors who lead smaller groups within the Component Group)
- Supervisors from Assembly
- Operators within each Component Group
- Assembly Line workers (multiple) representing each of the three (3) shifts
- Skilled-trades – Electricians, Millwrights, Pipefitters
- Plant Product Manger – Assembly from a separate powertrain plant (benchmarking)

Outside research was completed to better understand the applicability of Push vs. Pull systems and potential inventory management methods/models, as well as to develop frameworks for current and future organizational challenges.

## 1.6 Project Goals and Hypotheses

### Project Goals include:

- Provide a better understanding of the applicability and strategy for implementing a plant-wide Pull system
- Identify sources of schedule deviation in order to reduce or eliminate these deviations
- Provide strategies and tools for better inventory management at the component level
- Understand current production incentive structure to identify any alignment inconsistencies
- Identify challenges and strategies for ‘pulling change’ in a very traditional, tribal knowledge based culture
- Suggest strategies for knowledge transfer and skill retention in anticipation of the ‘demographic cliff’

### Project Hypothesis

One key driver to the success of ‘Pull-to-Assembly’ is that a highly synchronized and visible in-house inventory management structure must first be in-place. Successful inventory management requires that inventory levels for each component must be completely understood and tuned to the variety of the component, process lead time (throughput time), demand and variability in both lead time and demand. This thesis presents a variety of inventory strategies including a ‘calculator’ that allows the user to determine initial inventory levels appropriate for a given part based on the demand/lead time scenario.

In addition, a running theme evident throughout this study is the need for standardization and stability in a system before continuous improvement and change can be effective. A more statistically behaved process will produce improved process capability. This draws from the observations of previous thesis work done at 3WA by MIT Leaders for Manufacturing (LFMs) fellows Greg Dibb (2003) and Mark Stover (2004). In Dibb’s thesis entitled *A Study of the Mighty Motors Operating System: Making Sustainable Improvements at a Powertrain Manufacturing Facility*, he promotes the following observations:

*“Standardize all activities (by making them highly specified according to content, sequence, timing and outcome). Standardizing activities in this way improves the visibility of problems and provides a common basis for improvement. [In addition], standardize each link to create one clear, direct, unambiguous signal. Standardizing links (connections) between activities eliminates ambiguity and waste.”<sup>1</sup>*

---

<sup>1</sup> Dibb, Gregory David. “A Study of the Mighty Motors Operating System: Making Sustainable Improvements at a Powertrain Manufacturing Facility”. Published MBA/MS Thesis. Leaders for Manufacturing Program, Massachusetts Institute of Technology, Cambridge, MA. June 2004.

In Stover's thesis entitled, *Enabling Waste Elimination, Learning and Continuous Improvement through Standardization*, he builds on these notions and concludes that 3WA should:

*“focus on standardization to achieve sustainable continuous improvement. Without standardization, randomness and variability will hide the wastes and improvements will deteriorate.”*<sup>2</sup>

Finally, 3WA must also develop strategies for sustainability of organizational knowledge and skills. Not only is knowledge transfer more challenging in a tribal knowledge, relationship-based culture, but is becoming increasingly important as more and more employees approach retirement age. 3WA must identify where key skills and knowledge exist in the organization and become predictive about how and when they will transition or replace these competencies.

---

<sup>2</sup> Stover, Mark E. “Enabling Waste Elimination, Learning and Continuous Improvement through Standardization”. Published MBA/MS Thesis. Leaders for Manufacturing Program, Massachusetts Institute of Technology, Cambridge, MA. June 2005.

## 2 Push vs. Pull Systems

Many manufacturing companies wrestle with managing in-house inventories especially in the climate of Just-in-Time (JIT) manufacturing and pressure to reduce inventory levels. One popular self-managing approach to controlling inventory levels while being responsive to the customer is implementing a 'Pull' system. A Pull system is one that takes production signals from the downstream process and is based on true customer demand. Under this scenario, a part or batch of parts are processed only when the downstream customer (next process step) consumes a part (or batch of parts) and then signals the previous process to 'make more' in a quantity specified by the signal. The most typical version of signal is a Kanban Card (also called Pull Card); a sample is shown as Figure 2-1 below.

<b>PULL REQUEST TAG</b>
Part X
<i>(INSERT PHOTO OF PART X)</i>
Part Number 123456
SUPPLIER / CELLS POWDERCOAT
CUSTOMER / CELLS UPPERS AREA A
MAX PARTS / LOAD 25

**FIGURE 2-1 – Sample Kanban Card: physical signal from customer to supplier to 'make more'**

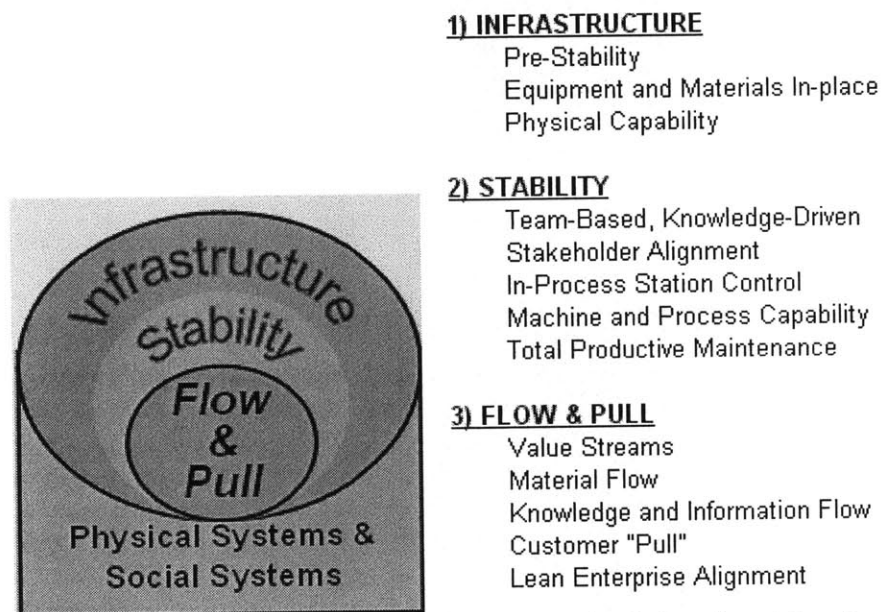
In contrast, a 'Push' system takes the production signal from the upstream schedule. Essentially, each subsequent processing step processes whatever is delivered by the previous step. At the very beginning of this process is a forecasted schedule that tells the first process what and how many to make and that is what is then 'pushed' through the system to the end. The Push system produces products independent of actual customer demand (assumedly, the forecasted schedule is based on predicted customer demand, but this is not 'true' or actual customer demand).

3WA PTO has decided to implement a plant-wide 'Pull-to-Assembly' strategy in an effort to respond to actual customer demand while maintaining minimal inventory levels. At the time I arrived in mid-June 2005 at 3WA PTO, I observed several limited process steps where different component groups had implemented a Pull system, however, the Pull system was not being used throughout all processes of all component groups. Also at this time, I observed the implementation of an extensive Pull system through one of the processing areas called Powdercoat. This implementation had realized some success, however, had also experienced some struggle. The Powdercoat Pull implementation will be discussed in more detail in Section 2.3 to follow.

The following sections will discuss the foundational systems and stability that must be in-place before Pull can be successful. In addition, I will compare and contrast pure Push and Pull systems to gain a better understanding of the needs, pros and cons of each of these systems. This comparison will form the basis for the discussion about placement of Pull mechanisms and explain why a most real-world systems are actually a mix of Push and Pull, or more of a hybrid system.<sup>3</sup> I will complete the Chapter by discussing the Powdercoat Case Study and make some suggestions of what the full 'Pull-to-Assembly' implementation might look like – not actually entirely Pull.

## 2.1 Foundation and Stability Before Pull

Figure 2-2 illustrates the need for system infrastructure and stability before a flow and pull system can be successfully implemented. This means that you need the physical and social systems in-place to support a Pull implementation effort.



**FIGURE 2-2 – Before Flow and Pull, must first have stable physical and social systems<sup>4</sup>**

As noted before, implementing a Pull system is often the answer to working towards Just-in-Time (JIT) production and inventory reduction. In fact, an ideal JIT system would actually have zero-inventory. Most people understand that in the majority of production environments, zero-inventory is not a reality. It does, however, speak to one of the reaching goals of JIT. A summary of the JIT goals in a perfect world include (reality intent of goals noted):<sup>5</sup>

- Zero defects – high quality
- Zero (excess) lot size – lot size of one or minimal batch sizes
- Zero setups – reduce batch sizes which reduces inventory
- Zero breakdowns – reduce inventory needed to buffer downtime
- Zero handling – reduce inventory need to cover handling time

<sup>3</sup> Hopp, Wallace J. and Mark L Spearmann. *Factory Physics*. 2<sup>nd</sup> Ed. 2001. Chapter 10.

<sup>4</sup> Adapted from course lecture by Joel Cutcher-Gershenfeld. "Lean Six/Sigma Systems, Opening Session, SPL 1.0". ESD.60 Lean/Six Sigma Systems for MIT Leaders for Manufacturing (LFM) Program, Summer 2005

<sup>5</sup> Hopp, Wallace J. and Mark L Spearmann. *Factory Physics*. 2<sup>nd</sup> Ed. 2001. Chapter 4, Section 4.1.

- Zero lead time – reduce inventory needed to cover demand over lead time
- Zero surging – level demand and product mix to reduce excess work-in-progress (WIP)

These goals imply a minimum amount of system stability that must be in-place to enable a Pull system. Sections 2.1.1 through 2.1.6 describe the type of physical and social systems that must be in-place and stable for a Pull system to be successful and also refer to the current state at 3WA PTO.

### 2.1.1 Production Smoothing

For Pull to have a chance, the production plan, in terms of product mix and volume, must be leveled and a final assembly plan sequenced. Currently, 3WA PTO Assembly does run on a smoothed and sequenced schedule, so this system is in-place. However, the stability of this system is less than it should be for best conditions of Pull implementation. If we consider schedule deviations from Cuts only (there are other types of schedule deviations, but Cuts account for the majority), an average of 38 Cuts per shift were experienced during an average 338 unit per shift production schedule<sup>6</sup>. Over 10% of the sequenced schedule experienced deviation. This must be improved before plant-wide Pull implementation would be recommended. Later Chapters will suggest possible methods to decrease schedule deviations.

### 2.1.2 Capacity Buffers

Buffers exist to cope with unexpected disruptions such as schedule changes or machine downtime. A common approach used by many manufacturers is to use a capacity buffer such that the facility is scheduled less than 24 hours per day which gives production an opportunity to catch-up. Similarly, if production gets ahead of the scheduled rate, workers may be sent home or directed to other tasks. These actions recognize that getting too far ahead in the schedule has the same effect on process suppliers as getting behind; they would be performing production outside of the expected schedule.<sup>7</sup>

Some also use overtime as an alternative to work-in-progress (WIP) buffers, however, this approach cannot prevent downstream processes from starving if there is a failure in the system upstream. Currently, 3WA PTO runs a 24 hour per day operations with three consecutive eight (8) hour shifts. When unexpected disruptions occur, areas that are capacity constrained have no time to ‘catch-up’ and this can affect all downstream processes.

### 2.1.3 Setup Reduction

Setup times will determine how flexible a system is to sequencing a mixed product schedule because long changeover times will prohibit producing different products based on true customer Pull. 3WA must consider each component process separately by looking at changeover times and component variety to determine how well that component process will be able to respond to a Pull signal and what order quantities would satisfy customer needs over the changeover time. If the order quantities would be prohibitively large, then this portion of the process may not be a good candidate for Pull.

### 2.1.4 Cross-training and Plant Layout

A JIT system and, therefore, a Pull system requires multifunctional workers who can move where needed to maintain flow. In addition, having workers with numerous skills can add flexibility to an otherwise inflexible system and allow them to better cope with product mix changes and other production deviations. At Toyota, a worker rotation system was implemented such that workers (and managers) were rotated through multiple jobs in the shop. This can be more difficult in a Union shop like 3WA PTO

<sup>6</sup> Production and Cuts data collected by the author for each of three shifts, over normal five day work week (excluding holidays) from July 11, 2005 through December 23, 2005.

<sup>7</sup> Hopp, Wallace J. and Mark L Spearman. Factory Physics. Chapter 4, Section 4.4.2.

because of established job classifications, but the added flexibility could be worth investigating with labor relations. I did observe a good deal of cell manufacturing set-ups at 3WA PTO, so they are clearly well aware of and practicing good plant layouts to maximize worker productivity and flexibility. In addition, Union leaders have been evaluating what can be done to enable more worker flexibility through cross-training and modified job classifications.

### **2.1.5 Quality Control**

JIT and Pull requires a high level of quality to function. In addition, for constant flow of parts through Pull while maintaining minimal inventory, scrap levels and rework must be very low. Therefore, when evaluating a process for implementation of Pull, the process quality must be extremely high with very low fall out. Quality control is a well monitored metric at 3WA PTO and, overall, scrap levels and rework are fairly low.

### **2.1.6 Product Introduction**

JIT and Pull requires a high level of stability and predictability in the system. To achieve this, statistically behaved process capability must be achieved. This is a continuing challenge at 3WA PTO where products are revised on an annual basis with each new model year. The most predictable and reliable way to reach this end is proper process prove-out. As part of new product development, 3WA should be concurrently developing production processes and equipment strategies. It was my observation that, currently, the product development process is leading rather than cooperating with development of production processes. Therefore, at times a process, after being put in place, would not operate up to planned specifications. This is an area ripe with improvement opportunities at 3WA.

## **2.2 *When to Pull – When to Push***

As inferred above, the work release method and where this signal comes from is the primary distinguishing factor between a Pull and a Push system.<sup>8</sup> In addition, there are production attributes and customer needs that also distinguish Pull from Push. A comparison of these attributes are detailed in Figure 2-3 below. Each system is compared based on the source of the production signal, the lead time needs, product variety, predominant location of inventory, system drivers and general pros and cons.

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<sup>8</sup> Hopp, Wallace J. and Mark L Spearman. Factory Physics. Chapter 10.

	PULL SYSTEM	PUSH SYSTEM
PRODUCTION SIGNAL	From downstream process - based on true customer demand	From upstream process - based on scheduled/ forecasted demand
PROS	Can accommodate uncertain customer demand; very responsive to customer	Most flexible to product variety; less susceptible to longer lead times
CONS	Not as good for high variety of end products	Not as responsive to customer unless lead times are really fast
LEAD TIME NEEDS	Needs fast lead time to react to uncertain customer demand	Less susceptible to lead time because build to schedule
FAST LEAD TIME...	Drives decrease in inventory (not responsiveness to customer)	Drives responsiveness to customer
PRODUCT VARIETY	Good for low variety of end products	Works for high variety of end products
LOCATION OF INVENTORY	Most inventory in finished goods	Most inventory in raw materials

**FIGURE 2-3 – Pull and Push System Comparison**

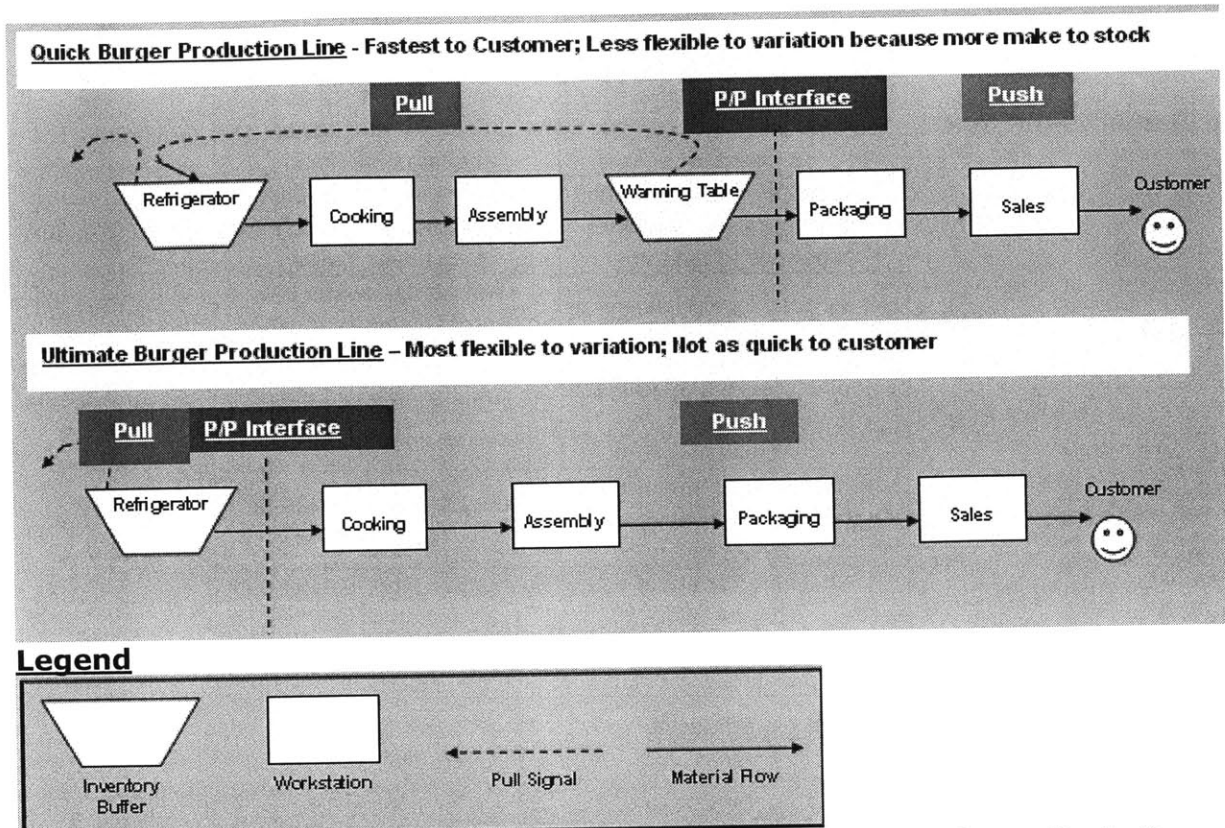
### 2.3 Pull-Push Interface

As mentioned above, it is more common for a plant-wide system to be a hybrid of Pull and Push rather than purely one or the other. The primary driver for this is different production items in the same plant that can have different variety attributes, lead times and customer needs. In this sense, it seems unreasonable to assume that all processes will be suited for a pure Pull system. It is more reasonable to consider the needs of each step of the greater system and the process as a whole and determine if Pull or Push best suits those needs. This establishes what is often called the Pull-Push interface and divides a process into Pull and Push segments.

To illustrate the idea of the Pull-Push interface, I have adapted an example from *Factory Physics*.<sup>9</sup> This is similar to the example I used when explaining this concept to the Managers at 3WA PTO to help them to understand Pull and Push and why a hybrid system can be the best of both worlds. This adapted figure is presented below as Figure 2-4. Let's think about two different approaches to making hamburgers (i.e., McDonalds vs. Burger King):

<sup>9</sup> Hopp, Wallace J. and Mark L. Spearman. *Factory Physics*. Chapter 10, Section 10.2.2.





**FIGURE 2-4 – Illustration of Pull-Push Interface: Quick Burger vs. Ultimate Burger Production**

You will note that the Quick Burger is more Pull and has the Pull-Push (P/P) interface closer to the customer. This system is very quick to the customer, but not very flexible to variety. In addition, to being quick to the customer, most of the finished inventory is at the warming table (near the end of the process). These are all characteristics of a system that is predominantly Pull.

In contrast, the Ultimate Burger line is more of a Push system with the P/P interface located very near to the beginning of the process. In this system, there is more raw inventory at the beginning of the process (refrigerated stock) and is very flexible to variety in the customer demand. In the Ultimate Burger line, which is predominantly a Push system, the customer can order any variety they want, but it will take longer than the Quick Burger (more Pull) system.

You can see that the system chosen will depend heavily on customer needs and the overwhelming trade-off between speed (more Pull) and flexibility (more Push). It is clear that if your process lead times are very quick already, then the customer will not feel a major difference between Push and Pull. However, the production inventory levels and the location of the majority of the inventory will look quite different in the two systems. Some additional observations can be made to help understand the Push vs. Pull systems and where to place the P/P interface:

- As a rule of thumb, if there is point in the system where heavy customization starts, place the P/P interface at that point. This will allow pooling of demand uncertainty.
- A system with very few end items (in terms of variety) can handle almost all Pull
- The size of the buffer at the P/P interface is determined by a forecasted schedule.



- The system will work to maintain buffer size by replacing what is consumed by the step after the buffer.
- Improving quick delivery to the customer, as in the case of the Quick Burger (more Pull), is only a benefit if the customer needs the product quickly.

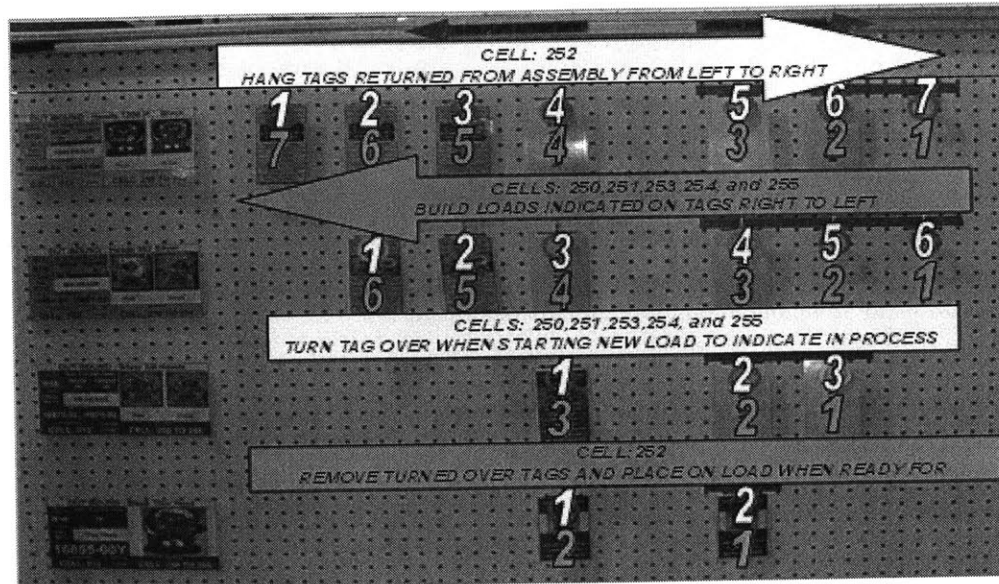
## 2.4 Pull Implementation Case Study: Powdercoat

Upon arrival at 3WA PTO, the Continuous Improvement (CI) group had already rolled out a full Kanban Card type Pull system at Powdercoat (aluminum parts painting area). In this system, a master board with all 26 varieties of parts was set-up at the parts painting loading area. The basic set-up established that each load of finished goods from Powdercoat was assigned a Pull card (from the master board) similar to the one shown in Figure 2-1. This card would travel with this finished load to its corresponding component group (the customer). As soon as that customer began to consume that load (started machining/processing), the card would be sent back to Powdercoat as a signal that another batch of that part variety would be needed. Based on typical daily demand, the Continuous Improvement (CI) group determined how many cards (loads) should be in the system to satisfy the daily needs of Assembly; this determined the WIP levels for each of the 26 part varieties.

The CI group performed extensive training of the Powdercoat staff on both shifts (Powdercoat is a two-shift operation) as well as staff from all of the affected component groups (on all shifts). This training consisted primarily of a 30 minute Powerpoint presentation complete with pictures showing examples of what the Pull cards would look like as well as what the board would look like (see Figure 2-5 below).



**FIGURE 2-5 – Example of Pull Board layout (as shown in training presentation)**



**FIGURE 2-6 – Example of Pull Board with use instructions (as shown in training presentation)**

### 2.4.1 Powdercoat Background

Powdercoat is an area of the plant that uses an electrostatic method to apply either black or silver paint to all aluminum castings. There are six (6) basic parts that are painted at Powdercoat before being sent on to their corresponding component group for further machining/processing before arriving at final Powertrain Assembly. Powdercoat supplies parts for all three of the component groups (Uppers, Lower, Transmission). In addition to the variety of silver or black, some parts are also unique to each of the three families of product. Considering both of these variety factors (color and family), Powdercoat manages approximately 26 different part numbers and runs on a two-shift schedule (1<sup>st</sup> and 2<sup>nd</sup> shift).

The complete Powdercoat process takes approximately two (2) hours. Parts are loaded in serial batches onto specifically designed hooks that hang on a track that travels at a rate appropriate for the paint process and the orientation of the part. Currently, based on the demand for each of the 26 parts, Powdercoat is nearly at maximum capacity. Because of this, decisions about which part to process next are crucial. In addition, it is also important to run the right mix and number of parts so as not to occupy precious Powdercoat time by processing either a part that is not yet needed or too many of another part. In addition to being capacity constrained, Powdercoat is also rendered somewhat inflexible both by the number of ‘hooks’ that can occupy a run as well as the changeover time required to ‘change hooks’ (different style hooks for different parts) for the next part load.

### 2.4.2 Powdercoat Pull Implementation

There were many aspects of the implementation of the Pull system that were highly successful, however, there were some existing physical system and social system challenges that inhibited complete adoption of the Pull system at Powdercoat while I was at 3WA PTO. As discussed above in Section 2.1, successful implementation of Pull requires both physical and social systems that will support the success.

To illustrate the scenarios that created obstacles to the success of the Pull system in Powdercoat, the following are two typical scenarios I observed. These scenarios also created barriers to trust in the system.

1. Powdercoat workers often talked about difficulty using the Pull board. At times, the location of some of the cards was unknown which made using the board for decision making less reliable. These sentiments are best illustrated by the following quote from a 1<sup>st</sup> shift Powdercoat worker: *“3<sup>rd</sup> shift is not doing it right [component groups not returning the cards], so when 1<sup>st</sup> shift shows up, we’re already screwed up and we don’t have time to hunt around for all the cards”*.<sup>10</sup>
2. Powdercoat workers also talked about their lack of confidence in the system because Supervisors would often bypass the Pull board and direct their own production decisions. It was common at the beginning of the shift for the Supervisor to meet with the Powdercoat workers and tell them the parts they needed to prioritize. Often, later in the day, the same Supervisor would come by again and bring another list of priority parts based on what he observed was low in inventory. There was an occasion where the Supervisor had just arrived from an ‘emergency’ meeting and said *“I just found out we’re going to need to paint more of part X, so ignore the Pull board for now and just make part X and I’ll tell you what to make next.”*<sup>11</sup>

### 2.4.2.1 Physical System Challenges

There are a number of physical attributes of the Powdercoat process that have made the Pull implementation less effective, as follows:

- **High product variety** – Powdercoat processes six different part groups that determine a variety of 26 parts when considering color and model family
- **Capacity constrained** - Currently, at a two-shift per day operations schedule, Powdercoat is nearing maximum capacity (their ability to produce as many parts as needed per the schedule).
- **Unscheduled demand hurts** – From time to time, Powdercoat must process orders outside of the daily scheduled demand. Not only do these unscheduled orders occupy valuable capacity, it also produces competition for parts needed to satisfy the component group needs for Assembly production.
- **Serving many customers** – In contrast to the component groups who produce parts for one customer – Assembly, Powdercoat is ultimately serving three (3) major customers (Uppers, Lowers, Transmission) all competing for the same Powdercoat capacity. A Pull system in which production signals come from many customers adds another dimension, which is a need to prioritize orders.
- **Far from Assembly** – Although Powdercoat is directly serving component group customers, they still serve the customer demand determined by the plant end customer, Assembly. This makes Powdercoat incredibly inflexible to deviations from the schedule because they are processing parts today that will not make it to Assembly for a long time compared to the component groups. That is, they are not able to react to today’s schedule deviations rapidly.
- **Physical inventory management** – The current layout for Powdercoat finished goods inventory is not disciplined. Areas for each of the six different part types have been informally established, however, because this is not entirely disciplined, the amount of finished goods inventory at any one time is not immediately visible. In addition, some of the finished goods inventory is stored at the corresponding component group.

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<sup>10</sup> Conversation with 1<sup>st</sup> Shift Powdercoat employee on August 15, 2005.

<sup>11</sup> Observation on 1<sup>st</sup> Shift Powdercoat, July 20, 2005.

- **Physical distance delays return of cards** – Similar to the proximity challenges with inventory, customers are located at various locations in the plant and it was common for a card to get ‘lost’ or otherwise delayed getting back to the supplier (Powdercoat). Timely return of the production signal is important for a Pull system to be able to level production to accommodate a capacity constrained resource.

### 2.4.2.2 Social System Challenges

Just as there were physical challenges for the Pull implementation at Powdercoat, there were also a number of social system challenges.

- **Training** – Although the training was widespread across all stakeholders and had support of leadership, it was relatively brief and focused more on the execution of the Pull system and less on helping the trainees to develop an intuition about why the system was needed and appropriate for that area of the plant. In addition, the training took place in a conference room rather than on the factory floor.
- **Leadership support** – This refers to both Supervisors at Powdercoat as well as higher level Managers. Although there was plenty of verbal support and head-nodding from both sources of leadership, the immediate and proximate reinforcement of the Pull system was not present. Both Powdercoat Supervisors had worked at the plant for more than 20 years and, under typical conditions, were able to manage Powdercoat well *despite* the Pull system. Although they both put forth physical effort to support the implementation, their actions did not always reinforce the necessary discipline of the Pull concept.
- **Lack of discipline and coordination between shifts** – because the Supervisors were not always making production decisions based on the Pull system, workers took this as a cue that using the system was optional. In addition, variability of commitment and system utilization between shifts caused frustration and lack of confidence in the system.
- **Power struggle** – Previous to implementation of the Pull system at Powdercoat, decisions about what to produce next were often made by a specific lead worker per shift. Under the Pull system, however, these decisions are basically made by the status of the cards on the Pull board. Consequently, the Pull system essentially takes away the perceived knowledge power from the lead worker. It was observed that these lead workers, in general, were not supporters of the new Pull system, likely because it removed some of their power and opportunity to garner respect from co-workers.

## 2.5 Plant-wide Pull Implementation at 3WA PTO

I believe that Plant-wide implementation of Pull at 3WA PTO is possible, but not in the sense that the entire plant will operate under a Pull system. As described previously, a more likely scenario is to evaluate each process on a case-by-case basis and determine where the Pull-Push interface should lie depending on factors discussed such as customer demand needs, lead times (throughput times), product variety, and inventory costs (both physical and monetary). An important aspect of any Pull system is the quality, consistency and type of signal from the customer to supplier. For example, at Toyota, the connections and signals are highly specific in their design. Toyota’s rule is:

*“Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses...Every connection must be standardized and direct...The rule creates a supplier-customer relationship between each person and the individual*

*who is responsible for providing that person with each specific good or service. As a result, there are no gray zones in deciding who provides what to whom and when. When a worker makes a request for parts, there is no confusion about the supplier, the number of units required, or the timing of the delivery.”<sup>12</sup>*

A final observation is best summed up by another quote from a worker in the Lowers component group at 3WA PTO who anticipated that the Pull system would be implemented in his group next:

*“You continue to hear ‘Pull doesn’t work’ and this attitude is contagious. People know that they are trying to implement ‘Pull’ at Powdercoat and at the same time, Powdercoat is not running well and so many people think that means that the Pull system is causing the poor performance.”*

This comment speaks to the importance of choosing an initial implementation location that will guarantee success rather than choosing the most challenging and impactful starting point. In this sense, because Powdercoat is by far the most challenging implementation (tied to all parts of the plant), it may not have been the ideal location to attempt initial, visible success. It is generally better to start with small successes and build from there.

## **2.6 Other Considerations for the Pull System**

A couple other considerations regarding Pull systems may be applicable to 3WA PTO, specifically. These include the concept of ‘Pull-from-the-Bottleneck’ and the debate of ‘Sequencing vs. Pulling’.

### **2.6.1 Pull-From-the-Bottleneck**

The Pull-from-the-Bottleneck concept ties into the idea that you never want your bottleneck process to starve. With a Pull system, the bottleneck is the customer that will send a production signal to a specified upstream supplier. A strategic buffer is then placed in front of the bottleneck such that the bottleneck will never starve for parts. As parts are consumed by the bottleneck, a signal is returned to the supplier to send more parts to the bottleneck. In this scenario, WIP is controlled by the Pull system up to and including the bottleneck. Under these conditions, the Pull-Push interface is at the bottleneck; processes before the bottleneck are Pull and processes after the bottleneck are Push (they get whatever the bottleneck processes). The caveat to this approach is if the bottleneck changes with product mix.

This ‘Pull from the Bottleneck’ approach may be most applicable in the Transmission area. The basic Transmission process flow includes the ‘Green Gear Side’ (initial grinding and some machining), Heat Treat (where gears are heated for annealing) and then the ‘Finished Gear Side’ (final grinding and machining). In this scenario, the bottleneck is the Heat Treat facility which can take up to 12 hours depending on the part being processed. The Heat Treat facility could send Pull signals back to the start of the Green Gear Side. The Finished Gear Side is much faster and more flexible compared to Heat Treat and could conceivably be treated as a Push system to process whatever comes out of Heat Treat.

### **2.6.2 Sequencing vs. Pull**

A frequent debate brewing at 3WA PTO was whether it was better to sequence parts to Assembly (similar to how Assembly sequences powertrains to their customer, the Final Vehicle Assembly plant) or purely implement Pull-to-Assembly, as the plant initiative suggests. I believe it boils down to the quintessential answer – ‘it depends’. Rather than address every component process and the pros and cons of sequencing each, I will instead suggest considerations most important to the ‘it depends’ solution.

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<sup>12</sup> Spear, Steven. “The Toyota Production System: An Example of Managing Complex Social/Technical Systems.” DBA diss., 1999.

- **Why are we sequencing?** –What are the advantages of sequencing parts over the Pull system?
- **Stability of process** – There is still a reasonable amount of daily deviation happening with the sequenced Assembly schedule. If this deviation can be reduced to a more manageable level, sequencing to Assembly may be possible.
- **Visibility of sequence schedule changes** – Currently, there is no real-time, quick visibility to the component groups for changes to the sequenced Assembly schedule. In order to be able to sequence parts to Assembly, an instantaneous signal would have to be sent to the component groups every time a schedule deviation occurred.
- **Flexibility of process** – The component group considering sequencing would have to determine if their process is flexible enough to respond quickly to schedule deviations and what level of schedule deviations would exceed their capabilities.
- **Where does sequencing start?** – Similar to the consideration of the Pull-Push interface, each process considering sequencing would need to determine where the sequencing process should start. The starting point for sequencing would likely be near the end of the process in order to be timely to the customer, unless the collective process steps were quick enough to respond sufficiently.
- **Benchmark Final Vehicle Assembly** – Currently, all parts provided to the Final Vehicle Assembly plants are sequenced and they perform this successfully. What are the enablers that they have found to make this system effective?

## **2.7 Final Thoughts on Pull-to-Assembly**

As illustrated throughout this section, the potential benefits of implementing a plant-wide ‘Pull-to-Assembly’ system at 3WA PTO are clear – become closer to ‘the ideal’ one-piece-flow/JIT and reduce unnecessary inventory. As a related benefit, the Pull system would allow the component groups to become more independent and less reactionary to the daily schedule and schedule deviations (which will be discussed in more detail in Chapter 3). When working properly, the Pull system should eliminate the bullwhip effect felt throughout the plant as each component group, with their varying throughput times, attempts to react to schedule deviations to make production decisions; the Pull system should make these production decisions for them.

The caveat for any Pull system is that it should not be implemented before both the physical and social systems have achieved a reasonable level of stability. As noted above, definitive initial success is imperative for the overall success of the implementation which depends so heavily on people who believe in it and will be disciplined enough to see it through expected ups and downs as the water is lowered and rocks start showing.



### 3 Sequencing and Scheduling

As evident in the discussion about implementing the plant wide ‘Pull-to-Assembly’ initiative, understanding how the plant schedules sequenced Powertrain Assembly is important to understanding how in-house produced parts flow through the plant. In addition, a basic understanding of this process is essential to understanding plant inventory management and what is driving inventory decisions. This section will explain how demand forecasting is used to build the 3WA PTO sequenced schedule, how finished powertrain units are physically sequenced for the customer, types of deviations to the schedule and the implications of such deviations to final sequencing, production and future scheduling.

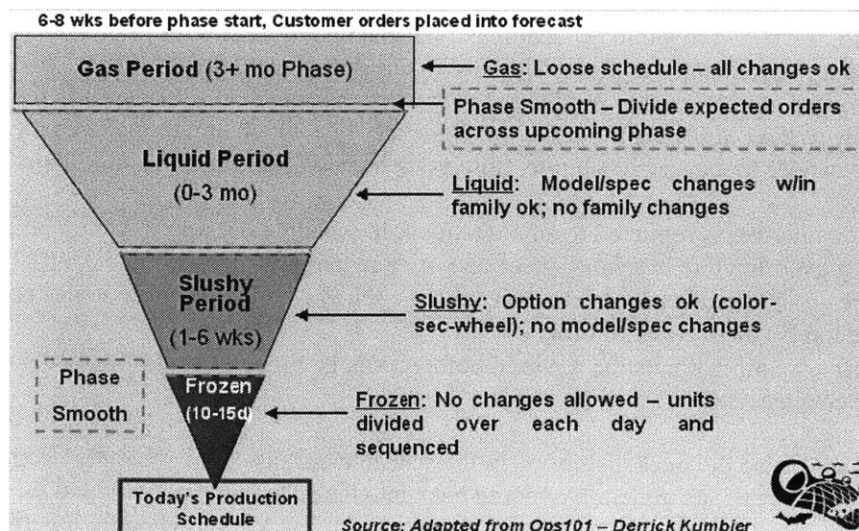
#### 3.1 Demand Forecasting and Scheduling

3WA PTO creates their sequenced schedule based on a quarterly managed demand forecast. The term ‘managed demand’ means that inside of three months of the production date, 3WA requires their customers to firm more and more order specifications as the production date nears. In fact, at three weeks prior to the production date, a customer is no longer able to make any changes to their order.

The year is divided into four, 3-month phases. Approximately six to eight weeks before the start of each phase, customer orders are placed into the forecast which is managed through four periods called Gas, Liquid, Slushy and Frozen to mimic how the forecast becomes more and more firm as the production date approaches.

- **Gas Period (3+ months from production date)** - any changes to customer orders are accepted
- **Liquid Period (within three months from the production date)** - no changes to the product family, but can change the model type and some other options
- **Slushy Period (three to six weeks from the production date)** – no changes to model type, but some options can be changed
- **Frozen Period (0 to three weeks from production date)** – no further changes allowed

Figure 3-1 below illustrates this funnel-type managed demand forecasting process. Note that between each of these phases there is a ‘phase smoothing’ process such that all scheduled units are spread across the upcoming phase in order to balance or level production.



**FIGURE 3-1 – Translation of Forecast to Production Schedule**

This Frozen schedule is first sequenced by the 3WA Final Vehicle Assembly plants and then the sequenced schedule is fed into the 3WA PTO scheduling system that sequences the powertrain units for the PTO based on plant specific scheduling constraints (e.g., only certain numbers of the same family of powertrain can be assembled sequentially and this determines the production pattern). Once the PTO schedule is sequenced, it is then manipulated to accommodate the truck loading method and orientation. Because the first unit unloaded at Final Vehicle Assembly will be the last unit on the truck at PTO, the sequenced schedule must be reversed and then sectioned by truckload and rack number/position. Each of the powertrain units are loaded on a rack holding either three or five units of a specific product family and these racks are stacked and loaded on the truck.

At this point, the PTO schedule is set based on the customer demand. However, because there tends to be some level of daily deviations from the schedule (which I will discuss in more detail to follow), the Scheduler must manually incorporate units that fell out of a previous day's schedule or special orders. At the PTO level, the Scheduler finalizes a production schedule two to three days prior to the powertrain production date. After the schedule is finalized by the Scheduler, any changes to the schedule will be considered schedule deviations.

### **3.2 Sequencing**

We now shift from the beginning of the process – scheduling, to the end of the process – sequencing. When the term 'sequencing' is used here, it refers to the physical act of a worker (a Sequencer) who places each unit onto its assigned rack. Racks are loaded based on a rack list that is developed from the finalized schedule. As with production, the racks are loaded in the order they will be placed on the truck (which, as a reminder, is the reverse sequence needed at Final Vehicle Assembly). It is appropriate to note here that the unit that is required for each rack position is a certain engine-transmission combination, however, is not a unique sequenced unit. In other words, if the rack required an A-B unit, any A-B unit made that day could be used to fill that spot, not necessarily an A-B unit from a specific Assembly sequence location. This is an important distinction because if each unit needed was uniquely positioned in the sequence and then one was Cut out of the schedule and not put back in the schedule for three days, the truck to which it was assigned would be waiting three days instead of just waiting for the next unit of that combination.

### **3.3 Schedule Deviations**

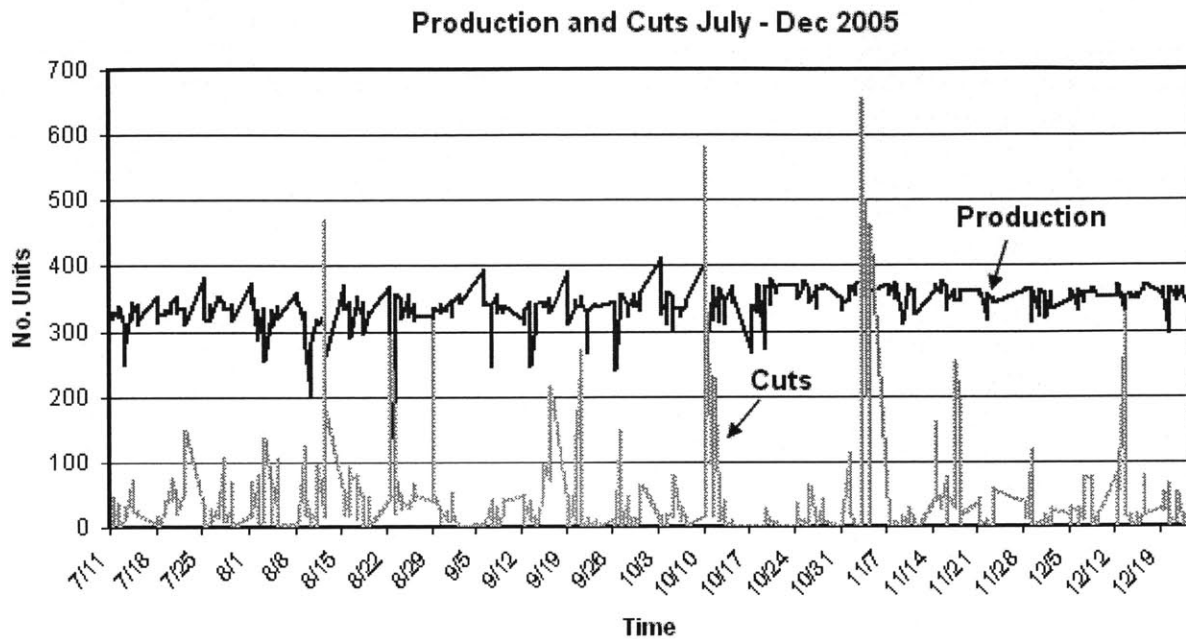
As described above, the PTO production schedule is finalized two to three days prior to the production date. From this point, any changes to this schedule are considered schedule deviations. Most of the time deviations do not occur until the actual production date when the schedule is loaded into the Assembly system that tells the worker at the beginning of the Assembly line which unit to make next. There are three basic circumstances that cause deviations from the schedule: Cuts, Inserts and Repairs.

- **Cut** – a unit that is removed from the sequenced schedule because it cannot be built at that time, most often due to a shortage of one or more parts.
- **Insert** – a unit that is added (inserted) into the schedule either because it was previously Cut (more likely) or is a special order
- **Repair** – a unit that must be repaired before it can be processed into finished goods and sent to the Sequencers

By all accounts, Cuts cause the most disruption in the schedule because they generally occur in larger numbers. In contrast, Inserts are generally worked back into the schedule gradually and Repair units are fairly infrequent. Because Cuts cause the most disruption to the 3WA PTO schedule, I performed a study of the root causes for Cuts in the hopes of eliminating or at least reducing the current levels of Cuts per



day. The following graph illustrates number of units produced and number of Cuts per shift over the period from July 11 to December 23, 2005:



**FIGURE 3-2 – Illustration of Number of Units Cut per Shift and by Model**

Over this period, the average production per shift was 338 units with a standard deviation of 32 units. The average Cuts per shift were 38 with a standard deviation of 75 units (range: 0 to 652 units). The standard deviation of Cuts is very high relative to the average Cuts per shift and supports the observation of the unpredictability and erratic nature of Cuts over this period. Also note that despite the occasional spikes in Cuts, production remains relatively steady which indicates that even though a large number of units are being Cut from the schedule, production continues. For production to continue despite high numbers of Cuts, Assembly must build much further forward in the future day’s schedule. As mentioned previously, many of the component groups struggle with reacting to such deviation from the planned schedule. The possible effects of this type of schedule deviation are discussed further to follow.

### 3.3.1 Distribution of Cuts

There are two central ways to evaluate Cuts. The first and easiest is to look at which component group or which shift is causing the most Cuts and for which family of product. This is easy because on a daily basis the numbers of Cuts are recorded and attributed to either Assembly or one of the component groups. The second is to identify other sources that have contributed to the Cuts. Because this is not data that is recorded directly, these are more observation-based reasons.

#### 3.3.1.1 Who Causes the Cuts?

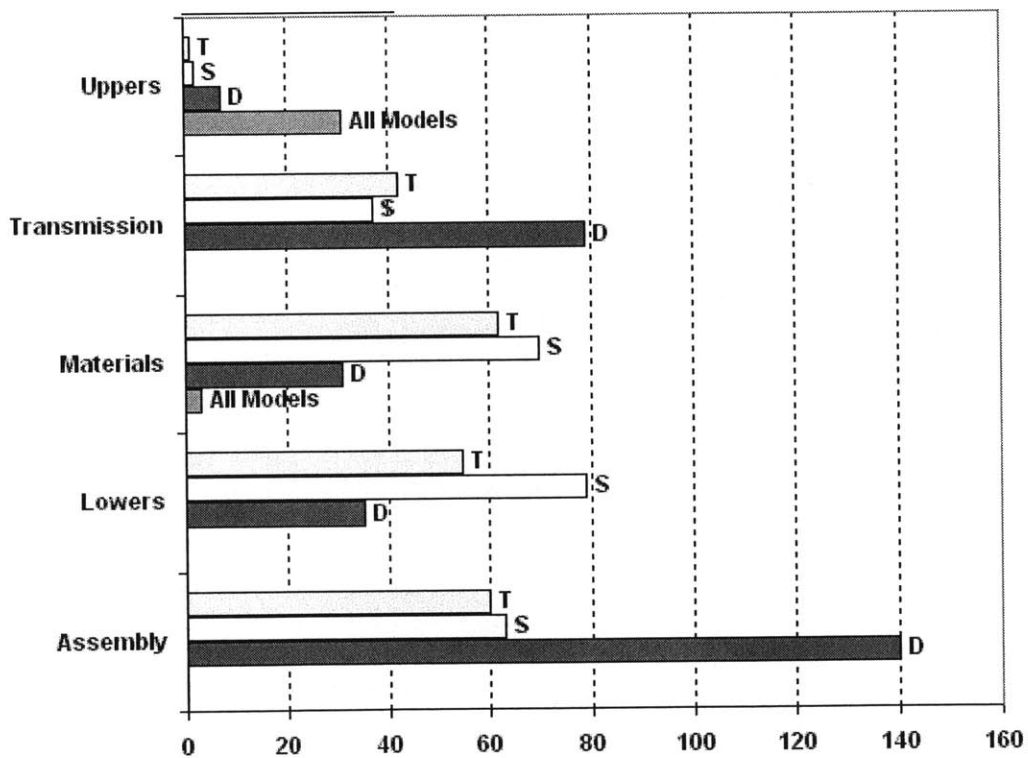
Here I will illustrate the distribution of number of units Cut over all shifts during the period from July 11 to December 23, 2005. This distribution is presented below broken down by component group/area, model and shift.

Table 3-1 and Figure 3-3 (built from Table 3-1) below show that overall, Cuts are distributed over all models fairly evenly with the highest number of Cuts attributed to Model D. Table 3-1 also shows that

the highest number of Cuts are attributed to Assembly. This is likely due to the fact that the Sequencers are part of the Assembly group and often 'Cut what they don't need and Insert what they do need for the truck'. It is also interesting to note that the Uppers group has the least number of Cuts over this period. The Uppers group has the least differentiated parts, that is, most of their parts are used in all models rather than being model specific. This supports the idea that forecasting demand for inventory management purposes is easier when demand is aggregated over all models rather than being model specific as in most parts attributed to Lower, Materials and Transmission. The Materials group listed below manages purchased parts from suppliers.

Area	All Models				Grand Total
	D	S	T		
Assembly	140	63	60		263
Lower	35	79	55		169
Materials	3	31	70	62	166
Transmission	79	37	42		158
Uppers	31	7	2	1	41
Grand Total	34	292	251	220	797

**TABLE 3-1 – Number of Units Cut per Component Group and by Model (D, S, T, All)**  
*Note: 'All Models' mean that the part causing the Cut is used in all models.*

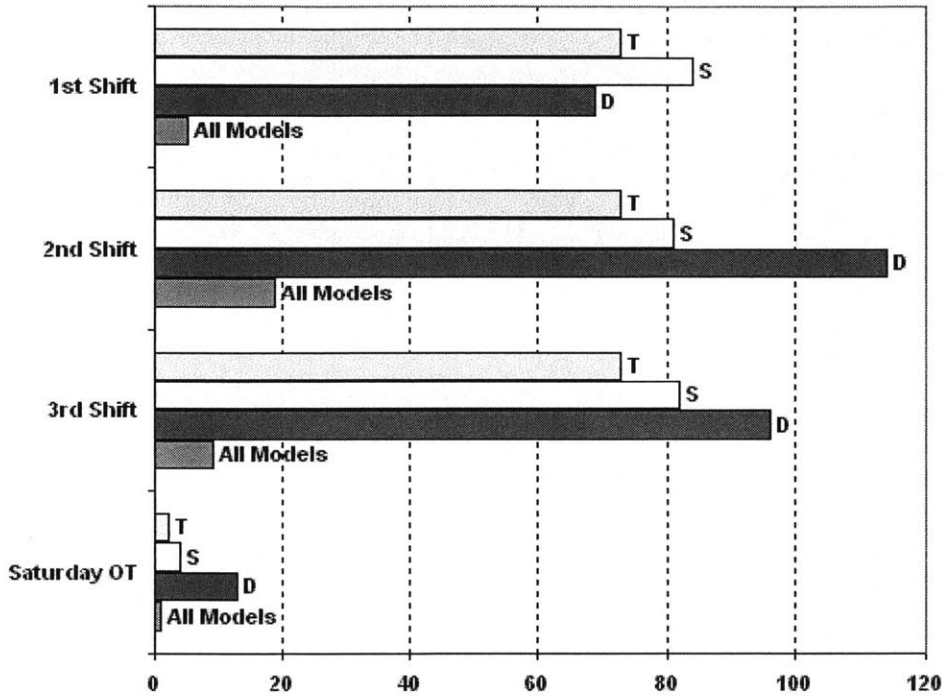


**FIGURE 3-3 – Illustration of Number of Units Cut per Component Group and by Model**

Table 3-2 and Figure 3-4 (built from Table 3-2) below show how Cuts are distributed over each of the three shifts and by model. There does not appear to be any significant difference in the number of units Cut per shift or which models are Cut. Second shift does have a slightly higher tendency for model D cuts, but not significantly so.

Shift	All Models	D	S	T	Grand Total
1st Shift	5	69	84	73	231
2nd Shift	19	114	81	73	287
3rd Shift	9	96	82	73	260
Saturday OT	1	13	4	2	20
Grand Total	34	292	251	221	798

**TABLE 3-2 – Number of Units Cut per Shift and by Model**



**FIGURE 3-4 – Illustration of Number of Units Cut per Shift and by Model**

These observations are strictly based on numbers of Cuts and do not illustrate the root causes of these Cuts. Root causes for Cuts are discussed in Section 3.3.2 to follow.

### 3.3.1.2 What Else Caused the Cuts?

More anecdotal observations regarding additional causes of Cuts are presented here as a collection of my own observations as well as those of workers who have been at the plant for a long time. I have only retained those observations which are supported by the actual data collected:

- **Building ahead in the schedule** – In an effort to ‘make the daily production numbers’, Assembly will build ahead into the next production day’s schedule when a significant portion of the current day’s schedule was Cut (as described with Figure 3-2). Basically, they will continue to make only those units in the schedule for which they have all parts available until they assemble the number of units that is the accepted goal for that shift or day. This practice is enabled by the current scheduling process which finalizes two to three days of schedule ahead of time in the case that ‘Assembly needs more schedule’.
- **Yesterday’s Cuts caused today’s Cuts (aka – Cuts beget Cuts)** – If enough of one type of unit is Cut from today’s schedule, Assembly will build further ahead in the schedule and ultimately

consume components that were not planned to be used until the next day. This unexpected consumption could cause Cuts the next day if the component groups are not able to react quickly enough to the unexpected consumption. This happens most often for those parts with longer lead times.

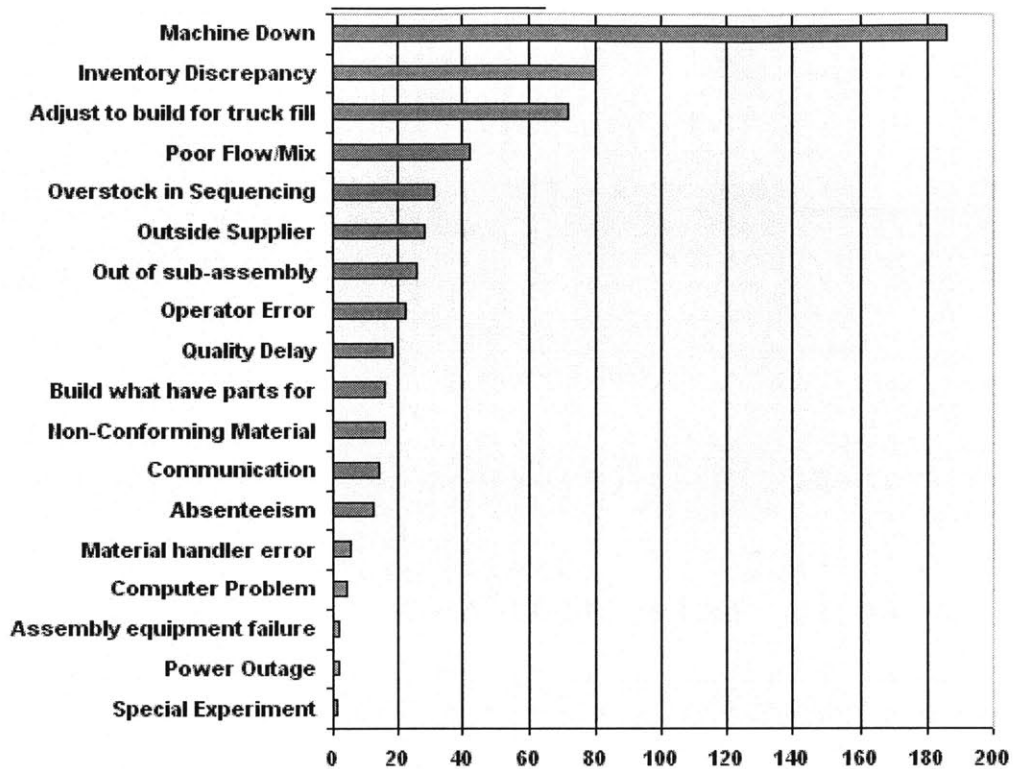
- **Too many independent decision makers** – Because there is not a quick formal or systematic method of communicating schedule deviations, many component group leaders are making one-off decisions about how to respond to schedule deviations they happen to find out about (which is not all of them).
- **Inserts matter too** – most Managers are focused on counting the number of Cuts per shift and Inserts are for the most part ignored. However, an influx of Inserts could have the same effect as too many Cuts; both are deviations from the planned schedule.
- **Different component groups are living at different points in the schedule** – As alluded to before, some component groups have parts with lead times up to 12 hours. Clearly these areas will be the least likely to be able to respond to significant schedule deviations and may get criticized more often simply because they have slower reaction time.

### 3.3.2 Root Causes of Cuts

Section 3.3.1 above explains how Cuts are attributed to the different groups at 3WA PTO, but does not indicate why these Cuts occurred. In addition to recording who was 'officially' responsible for these Cuts, I also determined the root causes of all Cuts over the same period from July 11 to December 23, 2005. The following were found to be the top five root causes of Cuts. A full distribution of root causes of Cuts are shown in Figure 3-5 that follows.

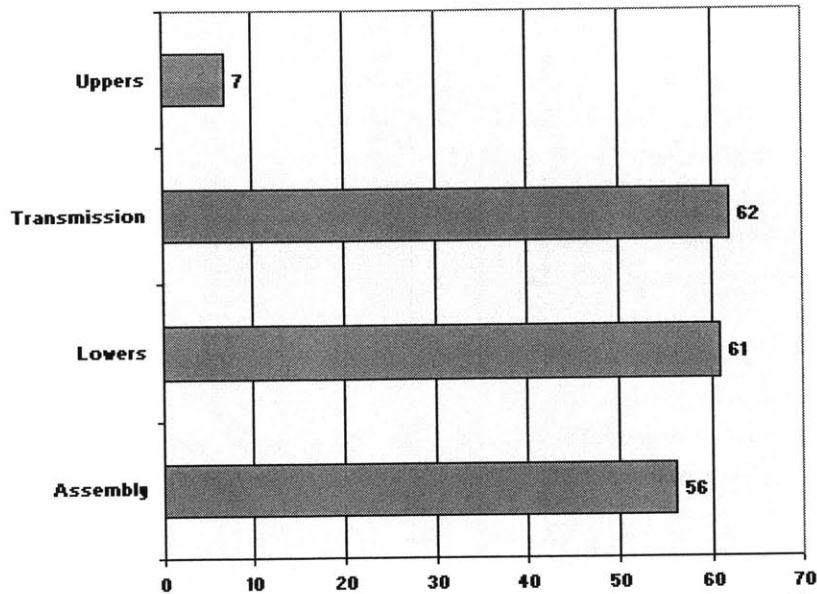
#### Top Five Root Causes of Cuts

1. **Machine downtime** – downtime can inhibit ability to make as many parts as needed
2. **Inventory discrepancy** – fewer parts than they thought they had - miscounting
3. **Deviate schedule to fill truck** – Cut a unit not needed yet to Insert a unit needed to fill the truck
4. **Poor Flow/Mix** – made too much of one part and not enough of another; lack of visibility in the process where multiple parts share a process flow
5. **Overstock in Sequencing** – Sequencing has an upper limit capacity for holding finished units before racking them and loading on a truck. If sequencing is 'full', they must Cut units they do not need and Insert the ones they need (similar to No. 3)



**FIGURE 3-5 – Number of Cuts per Root Cause**

Since so many Cuts are attributed to machine downtime, I wanted to determine if this was more prevalent in any given area. Figure 3-6 below illustrates the distribution of Cuts with root cause of ‘machine down’ specifically. As shown, the Uppers component group has a much lower incidence of Cuts caused by machine downtime than any other component group. The other component groups/areas appear to have similar levels of machine downtime Cuts indicating that this is generally a plant-wide issue. Note that addressing machine downtime is not within the scope of this project, but is clearly an area for improving opportunities for future work.



**FIGURE 3-6 – Number of Units Cut Due to Machine Downtime per Component Group**

The second highest root cause for Cuts is ‘inventory discrepancy’ and may relate to a lack of process capability in some areas. This again supports the need for new product process prove-out to make sure the process is capable of producing enough parts to keep up with Assembly. Note that some of the ‘inventory discrepancy’ data is attributed to the Materials group based on parts from Outside Suppliers. In these cases, parts were used at a rate faster than expected and they ‘ran out’ before the next order arrived.

The last three of the top five root Causes for Cuts including ‘adjust to build for truck fill’, ‘poor flow/mix’ and ‘overstock in sequencing’ all relate to the need for better adherence to the sequenced production schedule and improved visibility for in-house managed inventory. Both of these topics will be addressed in later discussion.

### 3.3.3 Cost of Cuts

It is difficult to attribute a real cost to a Cut because all Cuts are not created equally. What I mean by this is that some unit combinations are produced in high volumes and some at lower volumes. High volume units are termed ‘high runners’ because they account for over 80% of daily production volume, but spread over only 30% of the model numbers (model combinations). In contrast, low volume units or ‘low runners’ account for only 20% of the daily production volume, but include over 70% of the model numbers. Loosely, a high runner is a model combination that is produced in high volume every day. Conversely, a low runner is a model combination that is produced in very low volume (less than 10) every day or not even every day (more than 50).

As described in the discussion of scheduling, different models are distributed throughout the day’s schedule (leveling) and so a high runner will occur in the schedule more frequently than a low runner. As a result, when a low runner unit is Cut out of the schedule, it will be much longer before that type of unit shows up again in the schedule. This can cause serious delays for the Sequencers who are looking for specific unit combination to fill each rack in a specific order. If a unit is not available because it was Cut earlier in the day, the Sequencer may not be able to complete that rack, which also means a truck cannot be loaded. Under these conditions, one ‘missing’ unit really could hold up a truck – that could be costly!

Based on these observations, one way to capture the cost of a Cut is to determine the costs associated with probable waiting time for the next of that unit. That is, if a given unit is Cut out of the schedule, we need to determine the expected amount of time before that unit shows up again in the schedule and who is waiting for that unit. Table 3-1 below provides estimated costs of Cuts for high runner versus low runner units. The distinction is shown by the average units per day produced of each type of unit. This scenario assumes that 1000 units are produced per day and that production runs continuously 24-hours per day. In addition, it is assumed that on average there are four (4) workers waiting for each unit. Therefore, the cost of a Cut is simply the average waiting time multiplied by the number of workers waiting for the unit multiplied by an average hourly wage of \$28/hour. Note that all numbers have been disguised, but demonstrate relative differences and support the same conclusions. Contracted breaks, lunch and other unexpected line downtime were not included in these calculations, but would increase the waiting time and, thus, increase Cut costs.

<i>Assuming 1000 Unit Average Production Per Day</i>	<i>Average Units/Day<sup>(1)</sup></i>	<i>Frequency (every Xth unit)</i>	<i>Average Waiting Time (minutes)</i>	<i>Average Waiting Time (hours)</i>	<i>Estimated Cost to Cut This Type of Unit<sup>(2)</sup></i>
Very High Runner	275	4	5.76	0.10	\$11
High Runner	60	17	24.48	0.41	\$46
Low Runner	7	143	205.92	3.43	\$384
Very Low Runner	1	1000	1440.00	24.00	\$2,688

<i>Who is waiting?</i>	<i>No. of Workers</i>
Sequencers	1
Dock Workers	2
Truck Driver	1
	4

(1) All numbers disguised - for discussion purposes only  
 (2) Assume an average hourly wage rate of \$28.00/hour

**TABLE 3-1 – Cost of Cuts for Different Frequency of Production Units**

The difference between the Cost of Cuts for different types of units illustrates why not all Cuts are created equally and emphasizes the importance of getting a Cut unit back in the schedule as soon as possible. Clearly, when a low or very low runner unit is Cut out of the schedule, the implications to the Sequencers and final product delivery are much more serious. In addition, the basic finding of this ‘waiting time’ approach is in line with observations I made during a 3<sup>rd</sup> Shift Sequencing Observation Case Study described in more detail to in Section 3.4.11 to follow.

### **3.4 Impact of Schedule Deviations**

At the highest level, schedule deviations produce a lack of stability in the system that reaps barriers for driving continuous improvement. At a deeper level, schedule deviations such as Cuts impact each area of the plant to some extent. Here I will discuss how schedule deviations affect sequencing, overall production and scheduling.

#### **3.4.1 Impact on Final Sequencing**

The primary impact of schedule deviations to the Sequencers is that they are left waiting for units they need that were either Cut from the schedule or lost to Repair. When they do not have the units they need, they are not able to complete a rack and must either wait for that unit to show up before starting on the next rack (if it is a high runner unit) or have the dock set the rack aside while they wait for the unit they need to show up (if it is a low runner unit). In either case, there is some amount of waiting going on and there are costs associated with that waiting, as illustrated above in Section 3.3.3 and Table 3-1.



### 3.4.1.1 Planned vs. Actual Sequencing Case Study

With the knowledge that the Sequencers were frequently complaining that they were not getting all the units they needed when they needed them, I decided to do a brief case study to better understand the extent of this waiting. On August 30-31, 2005, I spent both 3<sup>rd</sup> shifts observing the planned versus actual conditions of the production schedule. As part of my case study, I obtained the actual planned production schedule and then throughout the shift, I recorded the sequence and model combination of every unit racked. I used this data to compare the planned schedule to the actual needs of the Sequencers to determine if the production schedule was delivering the units they needed when they needed them. My suspicion was that previous day's schedule deviations were causing a sort of phase shift to exist between the planned schedule and actual needs.

The data analyzed in detail were from 3<sup>rd</sup> shift, August 31, 2005. I also recorded the previous five shifts' total Cuts which were 38, 313, 48, 22 and 7 respectively. This establishes that there was some level of schedule deviation leading up to this shift. After comparing all data, I developed the following findings:

- 27% of the time a unit arrived at least 1 hour late (and generally longer)
- More than 50% of these 'late units' were low runners

I repeated this study on 1<sup>st</sup> shift September 1, 2005 and had similar findings. Because this was an extremely labor intensive data collection and analysis effort, I only completed this analysis twice. Further study could be performed to determine if the suggested and implemented process improvements had a 'real' impact on improving the scheduling and sequencing process.

### 3.4.2 Impact on Production

Here, the reference to 'production' is primarily geared toward the component groups. Schedule deviations affect production primarily when the deviations are significant enough in number to exceed the expected variability in demand of any given component group. In addition, component processes with the longest lead times (throughput times) will be most susceptible to unexpected schedule changes. Components that are not utilizing a Pull system tied to Assembly are using the planned sequenced schedule (and intuition) to plan production levels and these component groups are most susceptible to schedule deviations.

Most of the top root causes for Cuts relate to this issue as well as some others, including:

- Inventory discrepancy
- Adjust to build for truck
- Poor flow/mix
- Build what have parts for
- Communication

The root cause Cut data and overall statistics on Cuts (e.g., high standard deviation and broad range) clearly shows why reliance on the sequenced schedule to plan production is a losing battle.

### 3.4.3 Impact on Scheduling

The primary impact of daily schedule deviations on the Scheduler is the need for more manual manipulation to finalize the schedule. As described above, building the final PTO schedule is generally an automated process until schedule deviations must be incorporated back into the schedule. In addition, because 3WA PTO is a three shift operation, there is no opportunity for the Scheduler to make mid-week adjustments to 'catch-up' and so there are cumulative and propagating affects of schedule deviations throughout the week that are unavoidable.



In addition to schedule deviations causing difficulties for the Scheduler, there are also generally inconsistent practices of recording why the schedule deviation occurred. The Scheduler must understand why the deviation occurred to know whether the unit must still be built or if it was already re-inserted into the schedule. There is a need for more standardized processes in management and recording of all versions of schedule deviations including Cuts, Inserts and Repair.

### **3.5 Process Improvements**

A few scheduling and sequencing process improvements were implemented during the course of the project. In addition, further suggestions for future process improvements are provided below.

#### **3.5.1 Implemented Process Improvements**

- **Advanced low runners in schedule** – Based on the sequencing case study that showed over half of the units they were waiting for were low runners and generally received over an hour late, I worked with the Scheduler to perform an experiment whereby all scheduled low runners were moved earlier in the schedule by approximately 200 units (~4 hours earlier). Although I was not able to perform formal post-experiment data collection, the anecdotal evidence from the Sequencers indicated that overall the units they needed were available when they needed them more often than before this was implemented.
- **Balance Sequencer work** – In the process of performing the Sequencer case study, I noticed that the volume of the work per each of the two Sequencers was not balanced, but instead split about 60% vs. 40%. This was primarily due to the fact that each Sequencer was assigned to rack different families of units and the current production volume per family was not equally distributed. To remedy this imbalance, a work-sharing arrangement was developed by the Sequencers and an Assembly engineer to better balance the work. This also helped reduce some waiting time; when one Sequencer was ‘waiting’ for a unit they needed to complete a rack, they may be able to help the other.
- **Increased communication between Sequencing/Assembly and Scheduling** – The most surprising observation I made during my work with the Sequencers and Scheduler was that these two groups of people did not communicate despite the fact that they are so deeply connected by the sequenced production schedule. A major source of frustration for both groups was that there was no visibility of the difficulties or reasons for actions of the other group. I brought this communication gap to the attention of the Assembly Plant Manager who then scheduled regular half-hour morning meetings to get all parties in the same room to problem solve together. After initial frustrations were vented, many misconceptions were cleared and the two groups established regular communication outside of these meetings. The Scheduler and Sequencers went from never talking to having a brief update meeting every morning and establishing an open communication line such that Sequencers contacted the Scheduler immediately when they had a problem rather than waiting for the Scheduler to find out the next day. Upon visiting the Sequencers afterwards, one of them breathed a sigh of relief: “Things have gotten better”.

#### **3.5.2 Future Process Improvements**

- **Get Cuts back in the schedule sooner** – Currently, when a unit is Cut from the schedule, it must be worked back into the schedule by the Scheduler. As mentioned before, the Scheduler finalizes a schedule two to three days ahead of that production run. In this sense, a unit that is Cut today may not make it back into the schedule for another two to three days. This is more important for low running units that may not be on the schedule again until a day or more

after the unit is Cut. There is currently a mechanism that allows Assembly to re-introduce a Cut unit without going through the Scheduler, however, it is a tedious and manual process that must be performed by the Assembly Shift Supervisor. Currently, both of these Supervisors are extremely time constrained and will most often decide to let the Scheduler get the Cuts back in the schedule rather than attempt to do it themselves the same day. A more automatic and user friendly system of getting Cuts back in the schedule as soon as possible is needed.

- **Prioritize low runners** – Currently, there is no visibility to Assembly or Repair regarding which units are high runners and which units are low runners. Clearly, if a low runner is Cut from the schedule or ends up in Repair, this unit should be prioritized over a high runner Cut or Repair so that it gets back in the schedule as soon as possible. This would require system change, but would be a valuable lever to decrease impacts of schedule deviations.
- **Cut Metrics – ‘Not all Cuts are created equally’** – As illustrated previously via ‘Cost of Cuts’, not all Cuts will have the same cost and impact to production as others. Currently, the metrics surrounding Cuts revolve around numbers of Cuts per shift, per day and do not address the potential for variable impact. In order for more meaningful Cut metrics to be developed, 3WA PTO must create visibility to distinguish between low and high runner Cuts. Suggested metrics would then look like:
  - Low runner Cuts are bad in *any amount* because of the cost of waiting
  - High runner Cuts are bad in *large numbers* because some component groups are not prepared to react quickly enough to the resulting increased variability

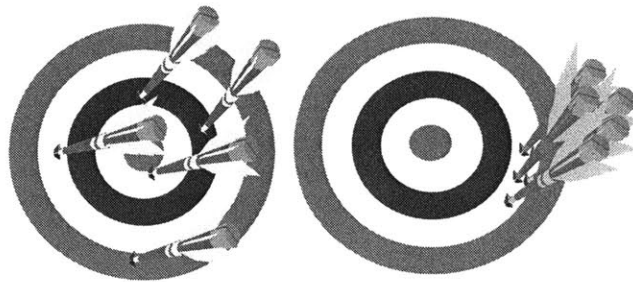
## 4 Internal Supply Chain Management

Now that an understanding has been established of the how the 3WA PTO operation looks in terms of developing a plant-wide Pull system and how production sequencing and scheduling is performed, the current methods for managing in-house produced parts will be considered. Included is a discussion of the current state of Supermarkets (finished goods inventories), parts counting, building to the schedule, isolated Pull systems and legacy management.

### 4.1 Current Parts Management Methods

Currently, there are a number of parts management methods being used by different component groups and different processes throughout the plant. In itself, utilizing different methods is not bad because many of these processes have very different production schemes. However, it appears that in many cases, people are managing or manually manipulating the system rather than the letting the system manage the process; this method lacks the type of standardization and stability needed for implementing a plant-wide Pull system as well as for providing an environment for continuous improvement.

An illustration of the importance of standardization and stability is shown below. Who did better overall and who will do better in the long run? Keep this in mind through the following discussion.



**FIGURE 4-1 – An Illustration of the Need for Standardization and Stability: Who did better overall and who will do better in the long run?**<sup>13</sup>

#### 4.1.1 Supermarkets and Counting Parts

This section will describe the current inventory management methods for in-house produced parts by describing the how finished goods Supermarkets are established as well as the control mechanisms utilized at the daily production meetings.

##### 4.1.1.1 Finished Goods Supermarkets

At present, each component group has a finished goods inventory holding area for all parts they produce in-house for Assembly and this area is called a Supermarket. Most of these Supermarkets are located at or as near to the point of consumption at Assembly as possible. At specified times throughout the day, material handlers visit these Supermarkets and deliver finished parts to the proper location along the Assembly line. If certain part inventories appear low at Assembly, the Assembly worker will notify their

<sup>13</sup> Adapted from course lecture by Joel Cutcher-Gershenfeld. “6 Sigma Systems Principles – Module 2.2”. ESD.60 Lean/Six Sigma Systems for MIT Leaders for Manufacturing (LFM) Program, Summer 2005.

Supervisor who will either have the material handler expedite the part from the corresponding Supermarket or, if the Supermarket is empty, will order Cuts for those units that require the out-of-stock part from the upcoming production schedule.

The size (holding capacity) of the Supermarket areas, in general, are determined by available floor space (which is limited in most areas of the plant). In addition, most Supermarkets have overhead signs indicating the number of parts per load as well as acceptable minimum and maximum parts levels. My observation was that most of these minimum and maximum levels were based on either anecdotal determinations (the amount that they found was usually sufficient to avoid Cuts) or available space in the Supermarket or some combination of both. The minimum was always greater than zero and so an empty Supermarket was always considered bad.

#### **4.1.1.2 Counting Parts and the Production Meeting**

Based on observed behavior at the daily production meetings, I suspected there was no plant-wide established system to determine appropriate Supermarket sizes. At the beginning of each shift, a brief meeting is held to discuss the planned production schedule for the upcoming shift, inventory levels of all parts needed at Assembly, down machines and any upcoming unscheduled production. To facilitate discussions at this meeting, there is a large dry-erase board listing all of the in-house produced parts for each component group with a space to enter the parts count for each shift, each day of the week. In addition to the part number, each listing provides the acceptable minimum (Min) and maximum (Max) number of parts in the Supermarket. At the meeting, it is common for the discussion to focus on the parts that are 'below Min' at that moment.

There are three main observations I drew from these meetings:

1. Many people spend a lot of time each day counting parts
2. The Min and Max levels are not frequently reevaluated to determine if levels are still appropriate. This was most evident when the Min and Max levels did not change after the start of the new model year product which was known to have a somewhat different color and family mix.
3. People are 'punished' for being 'below Min', but are rarely reprimanded for being 'above Max'.

My hypothesis based on these observations was three-fold. First, I believed that the reason workers were counting parts (other than they were told to) was that there was no immediate visibility at the Supermarket to determine where the inventory level was with respect to the posted Min and Max. Second, I believed that it was most likely that Min and Max levels were not reevaluated because there was no established simple and standardized way to do this. And third, there was no clear incentive for inventory levels to be minimized if people were not being held accountable for excess inventory 'above Max'. Based on these three hypotheses, I concluded that a more visual Supermarket set-up was needed and then set-out to develop a 'Supermarket Calculator' that would allow the component groups to take a logical 'first-cut' at reevaluating their Supermarket sizes whenever they suspected or were told about significant demand mix changes.

#### **4.1.2 Build to the Schedule**

Many component groups based their production decisions on the upcoming schedule discussed at the morning production meeting. This was particularly prevalent where there was no other production management system in-place, such as a Pull system. Because the customer (Assembly) demand is relatively steady (because demand is managed and leveled), building to the schedule is a viable approach as long as there are no significant schedule deviations. But as observed, no or low schedule deviations has not been a reasonable expectation to date.

In addition, there is currently no systematic, timely notice of schedule deviations to component groups. Therefore, even for components with relatively short lead times (those who may have a chance at reacting and adjusting production based on these schedule changes) generally do not have a real opportunity to do so. I did observe some of the short lead time component Supervisors attempting to keep up with hour-to-hour schedule deviations by regularly checking the computer system or checking with Assembly. However, this is clearly a very labor intensive and inefficient means to manage production decisions. In addition, ineffective and unclear signals from Assembly to the component groups can create problems with trust between these groups. This will be illustrated in later discussion.

### **4.1.3 Pull Systems**

Some component processes have implemented their own limited form of a Pull system. I define the existing Pull systems as limited for two reasons. First, in most cases where a Pull system exists, the system has not been implemented throughout the entire component group for all parts. For example, in the Lowers group, they have a Pull system that was implemented in flywheels, but not for other parts such as bearing plates. Second, many of the existing Pull systems have been applied to only a sub-section of the process. Most of these occasions look something like the ‘Pull-from-the-Bottleneck’ approach mentioned previously in Section 2.6.1.

These existing systems also illustrate how instrumental people and trust are in the success of any Pull system. The Pull systems currently in-place exist and are maintained because the operators want them. The operators realize that these systems empower them to make effective production decisions. The support and leadership of group management is another key contributor to the success of these systems. For example, the Pull system in flywheels was initially championed by a highly motivated Supervisor who implemented the system and encouraged its exclusive use. While I was there, there was a Supervisor change in flywheels. The new Supervisor wanted to be the one making production decisions and so abandoned the Pull system; the operators were disappointed, but felt pressure to follow the lead of the new Supervisor and so the Pull system was no longer used.

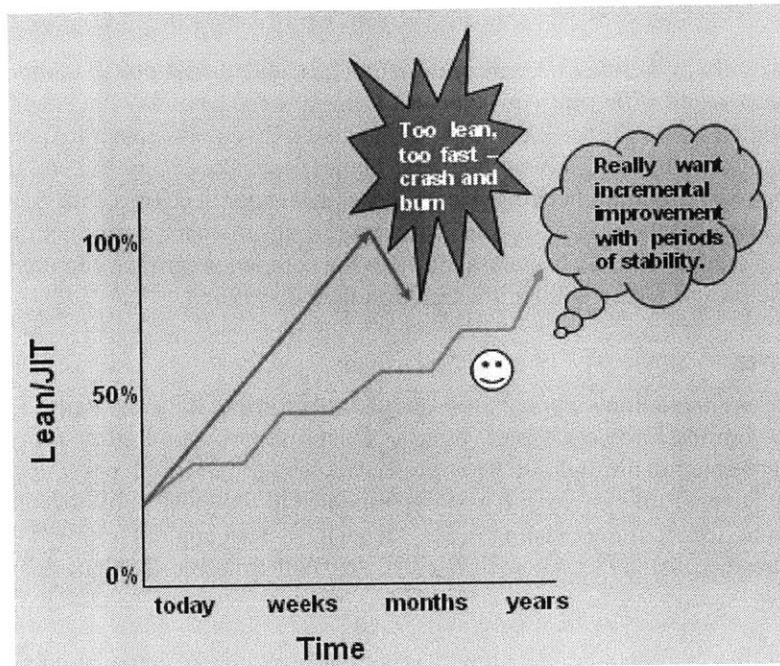
### **4.1.4 Legacy Management**

This example where the new Supervisor came into a new situation to do it ‘her way’ speaks to the prevalence of legacy inventory management at 3WA PTO. Many of the Supervisors have worked at that plant for over 20 years and have built an intuition about the needs of production in their particular component group. The discussion about the Powdercoat Supervisor who temporarily suspended use of the Pull board was utilizing his deep intuition to force the system to work. Although I cannot disagree that the component areas run by seasoned veterans are among the best run areas in the plant, this system of management is not available to the new Supervisors and so is not sustainable.

Standardization of how the operation is managed is the key to consistent success. The best operated areas lead by veterans will not make up for the lesser well run areas where new Supervisors are struggling to figure out the complexities and interdependencies of how parts flow through their system. I return to the illustration in Figure 4-1, shown previously.

## **4.2 Other Observations**

One of the biggest inventory management challenges at 3WA PTO was created a few years ago when management heavily championed JIT production. At the time, the push was to eliminate inventory and ‘get Lean’ quickly. Some current Managers observed that they tried to ‘get too Lean, too fast’ or ‘Lean overnight’ rather than implement a deliberate, step-wise approach to working toward reduced inventories and JIT. This is illustrated in Figure 4-2 below.



**FIGURE 4-2 - Lean/JIT is a journey, not a destination – filled with periods of leading progress followed by a need for stability and then more continuous improvements.**

One of the most illustrative quotes related to this ‘too Lean, too fast’ idea came from a veteran engineer who currently works in the Continuous Improvement Group. He was commenting on management’s attempt to rush to Lean and JIT and said it best when he stated:

*“We didn’t just lower the water, we drained the whole pond and now we’re trying to figure out how much water to put back in.”*

## 5 Inventory Management Methods

Most Managers at 3WA PTO recognize that JIT and one-piece flow is the nirvana, but not a reality for a plant with a reasonable amount of system variability. At the same time, inventory reduction is a continuous pursuit. Everyone understands that there are real business costs to having too much inventory including holding costs, impeding throughput, hidden quality and process problems, waste from excessive material handling and potential overproduction. At the same time, inventory acts as a psychological safety cushion for many Supervisors who understand that on many days, the Assembly schedule is not predictable enough to feel comfortable that minimal inventory levels will suffice.

In general, for inventory reduction to become possible, we need a reliable and stable process, nominal defects and short set-up times. Often the real first step in solving any problem is an understanding of what the real problem is. In this case, in my opinion, the real problem with schedule deviations is that there are too many daily occasions of part shortages. Based on the relatively stable, managed demand, this should never happen. One hypothesis is that the component groups may not understand how much inventory they really need to cover the daily Assembly demand as well as the expected variability in that demand as it relates to their specific component process. With this in mind, I set out to investigate possible inventory management and planning models and decide which model best suited the 3WA PTO production process.

This section provides a basic overview of potentially applicable inventory management models. There are two basic models applicable to the type of stochastic (random function) demand evident at 3WA PTO. These models include the QR Continuous Review Model and the Base Stock Periodic Review Model.

### 5.1 QR Continuous Review Model

The QR Continuous Review Model (QR model) is appropriate to use when inventory is monitored continuously and demand occurs randomly, and often in batches.

#### 5.1.1 Model Basics

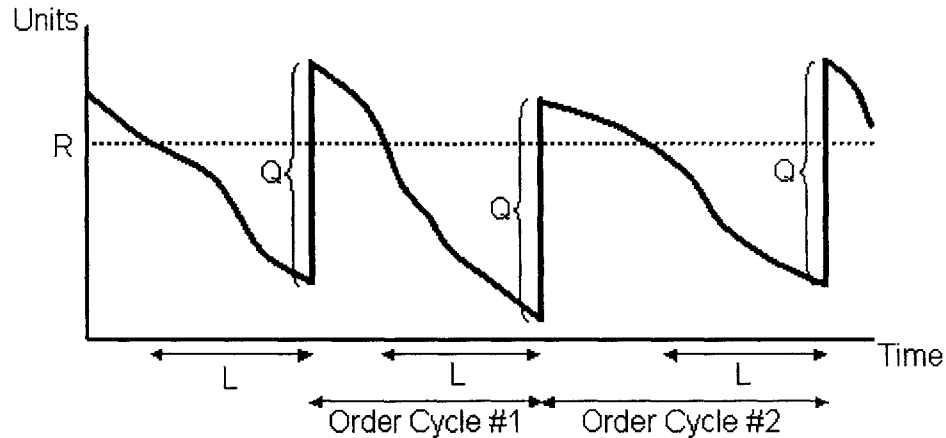
In the QR Model, when the inventory level reaches (or drops below) an amount  $R$ , an order size of  $Q$  is placed. The order  $Q$  is received after some lead time determined by the production process. The challenge in this model is to determine  $R$ , which is the reorder point and  $Q$ , which is the order size.

In the QR system, the time between orders varies (lead time), but the amount ordered is fixed (batch size). This is shown in Figure 5-1<sup>14</sup> below where order cycles #1 and #2 have variable lengths, but each has the same order size  $Q$ . The reorder point,  $R$  must be chosen such that enough inventory is available to cover the demand over the replenishment lead time,  $L$ . This model is most appropriate for high value items and when fixed order sizes are dictated by a supplier or set manufacturing batch sizes.

The QR Model is also often called the Min/Max policy where minimum inventory is set at  $R$  and the maximum is set at  $R+Q$ .

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<sup>14</sup> Figure 5-1 is adapted from a note "Inventory Basics" developed by Sean P. Willems, Boston University and presented in course lecture by Stephen Graves. 1.273 Supply Chain Planning, Department of Civil & Environmental Engineering, Massachusetts Institute of Technology (MIT), Cambridge, MA. Spring 2005.



**Figure 5-1: Continuous review policy (simulated values)**

### 5.1.2 QR Model Calculations

As noted above, R is typically set to cover the demand over the lead time with high probability. Another way of saying this is that we set R equal to the mean demand over the lead time ( $L \times \text{average demand}$ ) plus some number of standard deviations of lead time demand by the following equation:

$$R = L\mu + z\sigma\sqrt{L}$$

Where:

- R = Minimum inventory level
- L = lead time or replenishment time (time it takes to make a batch of parts)
- $\mu$  = average demand
- z = safety factor (corresponds to the number of  $\sigma$  of protection the safety stock will cover)
- $\sigma$  = standard deviation of demand

As noted above, in this case, Q is set to the batch quantity already determined by manufacturing rather than using an economic order quantity (EOQ) calculation. (Note: EOQ is essentially the calculated batch size that balances order costs with holding costs)

Under this model, the Min and Max inventory levels would be set as follows:

- Min = R
- Max = R+Q or some other acceptable level that makes sense for the operation

Similarly, Average inventory levels would be calculated as follows:

$$\begin{aligned} \text{Expected inventory level} &= \frac{Q}{2} + z\sigma\sqrt{L} \\ &= \text{cycle stock} + \text{safety stock} \end{aligned}$$

### 5.1.3 QR Model Sensitivity

Based on these calculation principles, we can draw a number of conclusions about what affects the QR Model:

- Increasing the average demand during lead time or the lead time will tend to increase the reorder point (Min), R.



- The higher the variability in the demand  $\sigma$ , the more inventory required (safety stock) to protect against stock-outs.

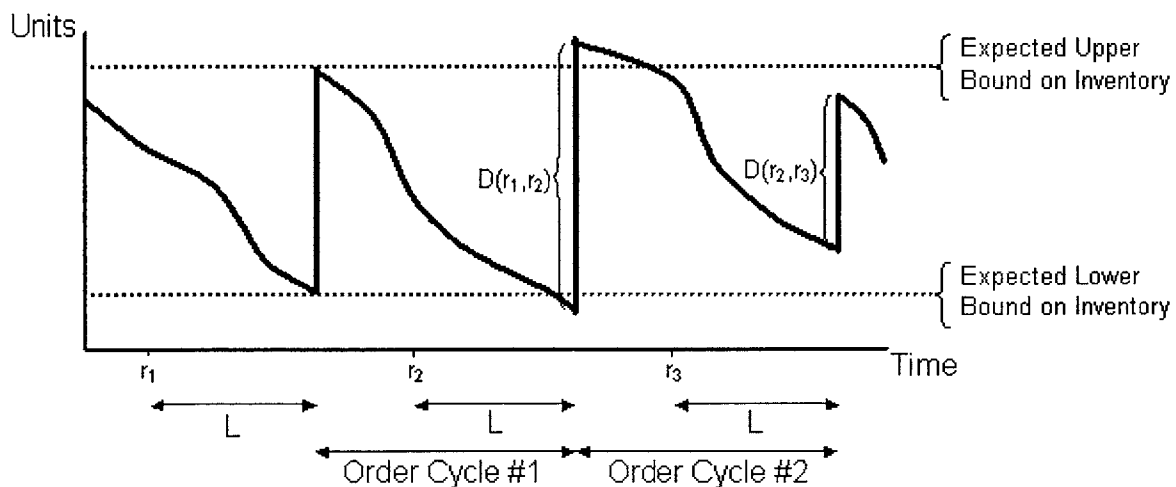
## 5.2 Base-Stock Periodic Review Model

The Base-Stock Model is a periodic review model that is appropriate when:

- Inventory is monitored at fixed intervals, such as might be determined by a supplier
- The ordering of two items must be coordinated such that they are replenished at fixed time intervals
- Item have small order volumes such that it is better to order them along with other orders
- Items have low value

### 5.2.1 Model Basics

In the Base-Stock Model, the inventory position is monitored and orders are placed at periodic, fixed intervals of length,  $r$ . In Base-Stock policies, the order is sized to bring inventory on-hand and on-order up to the base stock (upper bound) level and a fixed lead time (replenish time),  $L$  is assumed. In this periodic review system, the time between orders is fixed but the amount ordered varies. Figure 5-2<sup>15</sup> below illustrates how order cycles #1 and #2 are the same length but the amount ordered in each interval varies.



**Figure 5-2: Periodic review policy (simulated values)**

### 5.2.2 Base-Stock Model Calculations

As noted, it is the amount of the order that varies rather than the interval between orders for the Base-Stock Model. This model focuses on understanding the needs for the expected upper (base stock) and lower boundaries. The Base-Stock Model calculations are laid out as follows:

<sup>15</sup> Figure 5-2 is adapted from a note “Inventory Basics” developed by Sean P. Willems, Boston University and presented in course lecture by Stephen Graves. 1.273 Supply Chain Planning, Department of Civil & Environmental Engineering, Massachusetts Institute of Technology (MIT), Cambridge, MA. Spring 2005.

### Time Horizon and Variable Definition

- Start at time  $t=0$  and assume that  $B = \text{on-hand} + \text{on-order inventory}$
- When it is time to monitor the inventory levels, it is time  $t = r$  and an order amount equal to the demand since last review is placed.  $D(0, r)$  denotes the demand over the time interval 0 to  $r$ .
- The order will be received at time  $t = r+L$
- Expected inventory level for the first period is denoted:  $I(r+L) = B - D(0, r+L)$  and equal to the base stock level minus the demand observed between the start time  $t=0$  and the period time,  $r$  plus the lead time,  $L$ .
- Similarly, expected inventory for the second period is denoted:  $I(r+L_+) = B - D(r, r+L)$  and equal to the base stock level minus the demand observed between the first period time,  $r$  and the period time,  $r$  plus the lead time,  $L$ .

### Setting the Base Stock Level

The base stock level,  $B$  is set such that demand over the fixed order period is covered with high probability.<sup>16</sup>

$$B = \mu(r+L) + z\sigma\sqrt{(r+L)}$$

= Expected review period&lead-time demand  
+ safety stock

Where:

$B$  = base stock level (maximum inventory boundary)

$r$  = fixed review period length

$L$  = lead time or replenishment time (time it takes to make a batch of parts)

$\mu$  = average demand

$z$  = safety factor (corresponds to the number of  $\sigma$  of protection the safety stock will cover)

$\sigma$  = standard deviation of demand

### **5.2.3 Base-Stock Model Sensitivity**

The sensitivity of the Base-Stock Model is driven by similar variables as the QR Model. This is not surprising because both models determine appropriate inventory levels grounded in the idea of covering demand over lead time with high probability (e.g., based on variability of demand).

- Increasing the average demand during lead time or the lead time will tend to increase the base stock level,  $B$ .
- The higher the variability in the demand  $\sigma$ , the more inventory required (safety stock) to protect against stock-outs.

### **5.3 Comparison of QR Model and Base-Stock Model**

Overall, the QR Model most closely matches the production and ordering scheme at 3WA PTO. Fixed order sizes (batches) are produced in amounts to meet Assembly demand and the intent of modeling inventory requirements of Supermarkets is to hold minimum inventory while maintaining a high level of confidence that Assembly demand will be met every time. Therefore, the QR Model will be the basis of the Supermarket management tool developed for 3WA PTO for in-house produced parts. This is discussed in more detail in Chapter 6. Figure 5-3 presents a nice summary of the differences between the

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<sup>16</sup> Adapted from course lecture by Stephen Graves. "Inventory Basics". 1.273 Supply Chain Planning, Department of Civil & Environmental Engineering, Massachusetts Institute of Technology (MIT), Cambridge, MA. Spring 2005.

QR Model and the Base-Stock Model and illustrates quite clearly why the QR Model is appropriate for 3WA PTO.

<ul style="list-style-type: none"><li>• Q R model</li><li>• Fixed lot</li><li>• Variable time between orders</li><li>• A items</li><li>• Large setup costs</li><li>• Lot size dictated by process considerations</li><li>• Less inventory</li></ul>	<ul style="list-style-type: none"><li>• Base stock model</li><li>• Variable lot</li><li>• Fixed time between orders</li><li>• B/C items</li><li>• Shared setup costs</li><li>• Review prd dictated by process considerations</li><li>• Less transaction costs</li></ul>
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**FIGURE 5-3 – Comparison of QR Model vs. Base Stock Model<sup>17</sup>**

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<sup>17</sup> Adapted from course lecture by Stephen Graves. "Inventory Basics". 1.273 Supply Chain Planning, Department of Civil & Environmental Engineering, Massachusetts Institute of Technology (MIT), Cambridge, MA. Spring 2005.

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## 6 Applied Supermarket Management

As alluded to in Chapters 3 and 4, I concluded that lack of standardization and stability in current inventory management for in-house processed parts was a primary cause for schedule deviations as well as the most pressing underlying issue sabotaging current attempts at implementing Pull throughout the plant. Therefore, I set out to create a tool that could be used by all component groups to assist them in planning the amount of inventory needed to accommodate the existing demand variability inherent in Assembly production.

To measure the success of tool development, I established the following goals for the tool:

- Easy for everyone to understand/use with current level of system knowledge (e.g., would not require any training outside of reading a brief set of instructions)
- Utilizes data that is easily accessible to component group Managers and area Supervisors
- Has a simple and clean interface that plainly displays results
- Clearly communicates the uses and limitations of the tool

### 6.1 Right-Sizing Supermarkets

*“Inventory is not bad when it captures variability to isolate the Assembly line, but we need to make sure our Supermarkets are at the right level.”*

- 3WA PTO Manager in Production Meeting, June 24, 2005

I pitched my standardized approach to inventory evaluation to management by calling it ‘Right-Sizing Supermarkets’. Based on the quote above, I sensed the idea was taking hold and developing management support. Right-sizing Supermarkets merely suggested that 3WA PTO take a logical approach to determine the appropriate amount of inventory they should be maintaining to accommodate Assembly demand and variability without holding excessive inventory. Although this pursues the same objective as the current system, there was no existing standard approach to making the ‘right-size’ evaluation. As discussed in Chapter 4, several different approaches to inventory management were currently being used throughout the plant.

I proposed to 3WA PTO management and process group leads that getting all Supermarkets right-sized should lead to a decrease in part shortages to Assembly and thus greatly reduce Cuts. A significant reduction in Cuts would eliminate most schedule deviations and only then would the plant be ready to implement a plant-wide Pull-to-Assembly system. In addition, I suspected that having each of the area Supervisors and operators better understand the right amount of inventory they needed would help them to manage the flow of parts throughout their processes. This would be especially important for new Supervisors who did not have the benefit of legacy knowledge that their more senior counterparts possessed. Finally, having confidence in the amount of inventory needed would open up opportunities for more visual management techniques, which is another initiative that had been championed by management. I will discuss some of the visual management opportunities created by more informed inventory management in Section 6.5.

### 6.2 Defining Demand and Lead Time Variability

In order to build a tool to calculate Supermarket sizes, I had to understand the current demand and lead time variability to identify all the potential sources of variability and determine what variability data was readily available to component group Managers and Supervisors. I believed that using only easily accessed, existing data was the most important aspect of tool development because all potential users

were time constrained and would not use a tool that required them to spend time searching for information.

### **6.2.1 Demand Variability**

As discussed in Chapter 3, 3WA PTO benefits from the company-wide managed demand scheduling system where customer orders are controlled three months away from the production date and units are smoothed or spread evenly over those three months. At three weeks out, the schedule is ‘frozen’ such that customers can no longer make changes to their orders. After Final Vehicle Assembly Schedulers level and finalize the schedule, it is passed along to the 3WA PTO Scheduler who balances the schedule to meet the specific constraints of 3WA PTO Assembly while maintaining the final production sequence. As a result of this schedule smoothing or leveling process, the overall demand variability for any given powertrain unit is relatively low.

As mentioned previously, there are two major levers of variation of any given part including color or family specification. There are some parts that are common to every powertrain unit (independent of model family) and have no color distinction. Other parts are common to all powertrain units, however have the color distinction of black or silver. Some parts have a further distinction of being specific to one of three families of powertrain units produced at 3WA PTO. For purposes of discussion, these three families will be labeled S, D, and T. Different combinations of these variables determine the demand category applicable to each part. Three examples illustrate applicable demand categories depending on the type of part. Table 6-1 lists all possible demand categories and their corresponding average daily demand and daily demand standard deviations. As previously done, all numbers have been disguised to maintain confidentiality.

1. Rocker arm – common to all units, no color distinction – demand category ‘All Units’
2. Cylinder – common to all units, comes in black or silver – demand categories ‘All Black’ or ‘All Silver’
3. Crank Case – specific part for each of three families, comes in black or silver – demand categories include ‘S Black, S Silver, D Black, D Silver, T Black, T Silver’

DEMAND CATEGORIES	06 Average Daily Demand	06 Std Dev Daily Demand	Covariance ( $\sigma/\mu$ )
S BLK	320.00	16.96	0.05
S SIL	68.44	12.67	0.19
S CV BLK	2.76	1.98	0.72
S CV SIL	15.65	3.06	0.20
S CV TOT	18.41	4.07	0.22
S TOTAL	388.44	23.16	0.06
D BLK	133.47	21.02	0.16
D SIL	51.34	14.01	0.27
D TOTAL	184.80	20.13	0.11
T BLK	414.15	31.01	0.07
T SIL	74.74	5.64	0.08
T CV BLK	0.36	0.18	0.50
T CV SIL	15.99	5.68	0.35
T CV TOT	16.35	5.65	0.35
T TOTAL	488.89	31.46	0.06
CUR BLK	734.15	32.11	0.04
CUR SIL	143.19	12.05	0.08
CUR TOTAL	877.33	27.02	0.03
M TOTAL	184.80	20.13	0.11
ALL BLACK	867.61	44.79	0.05
ALL SILVER	194.52	21.10	0.11
ALL UNITS TOTAL	1062.14	37.15	0.03

**TABLE 6-1 – Average Daily Demand and Standard Deviation of Daily Demand for Different Demand Categories (for illustration purposes only - category names have been disguised and demand numbers have been altered)**

For planning purposes, average daily demand and standard deviation of daily demand can be obtained easily from the 3WA PTO Scheduler. In general, this can be done quarterly to correspond with the quarterly scheduling phases. For purposes of roll-out of the calculator tool (which will be discussed in more detail in Section 6.3 below), I provided a similar table for the current model year as well as the data forecasted for next year to accompany the calculator tool.

## 6.2.2 Lead Time Variability

Lead time variability is much tougher to capture than demand variability because there are many sources of lead time variability and, at present, this type of data is not collected consistently enough and in large enough volume to be meaningful at 3WA PTO. Primary sources of lead time (part processing throughput time) variability include machine downtime and queuing. Secondary sources of lead time variability include losses due to scrap or re-work.

### 6.2.2.1 Machine Downtime

As with many heavy manufacturing operations, machine downtime at 3WA PTO is a constant challenge and probably the largest overall source of lead time variability (also see 3.3.2 Root Causes of Cuts). Obviously, when machines are not running they are not processing parts and if a machine is down long enough there is an increased probability for shortage of parts to Assembly. The probability of parts shortage is even further increased if a machine early in long lead time process is down.

In general, the purpose of holding inventory is to fulfill average demand and demand over the lead time of that part. The longer the lead time and the more unpredictable the lead time, the more inventory needed to protect against stock-outs. This can create a ‘Catch-22’ situation in which excessive inventory levels are established to protect against high variability that is caused by an inherently unstable and flawed

system. This is the scenario often discussed to support JIT – too much inventory hides problems; in this case the problem would be a machine(s) that is down too often. A former 3WA employee shared this same observation and suggested potential solutions:

*“In order to achieve low inventories, a reliable plan must be in-place to quickly respond to machine problems and to eliminate recurring problems. Training machine operators to perform minor repairs, and providing the tools to do so can save significant amounts of machine downtime. Introducing preventative maintenance procedures that address the root cause of equipment failures provides a sound method of eliminating recurring problems.”<sup>18</sup>*

Another consideration with respect to production machines is determining if existing machines are flexible enough to handle the product variety demanded. When we talk about machine downtime, we often think about machine repair, however, another common form of machine downtime is set-up or changeover time. If lots of changeovers are required to process all product varieties and these changeovers are too long, then inventory needs will increase.

### **6.2.2.2 Queuing**

There are some parts that run through a single process and do not share machine time with any other parts. However, there are many parts that ‘share’ time either on a machine or through a common processing step. Wherever we have shared resources, we can expect some amount of queuing and this queuing time can be highly variable.

At 3WA, the biggest source of unpredictable queuing in the plant is the Heat Treat process. Heat Treat predominantly processes transmission parts (over a dozen parts), but also process a few parts from other component groups. At Heat Treat there are eight furnaces that run racks of parts through a five step process. The length of the five step process can vary anywhere from six to 12 hours depending on the ‘recipe’ required; there are four possible recipes. Because there are more parts than furnaces, Heat Treat must constantly make decisions and trade-offs about which parts will go through Heat Treat next. Clearly, there will be some queuing happening as parts wait their turn for furnace time. At present, queuing time for any given part is not recorded and so this large source of lead time variability cannot be captured directly.

Currently, for all parts that run through Heat Treat, the best lead time information comes from area Supervisors who have worked in areas such as Transmission for a very long time and ‘just know’ about how long it takes to get a part through all Transmission processing steps. This anecdotal data will be the data used in the calculating tool and, thus, creates one of the limitations of the tool; a solution is only as good as the data that builds it.

## **6.3 Supermarket Calculators**

After making substantial observations about the type and availability of demand and lead time data, I approached the development of a Supermarket calculation tool. As discussed in Chapter 5, the QR Model provided the most appropriate basis for the tool. Here I will discuss the tool mathematical basis, purpose, data entry instructions, limitations and measurement against development goals. There are actually three portions of the overall Supermarket Calculator including the Right-size Supermarket Calculator, the Lead Time Reduction Supermarket Calculator and the Planned Downtime Bank Calculator. The purpose of all three will be discussed.

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<sup>18</sup> Glusick, Daniel E. “Waste Reduction and the Need for Change at [3WA]”. EM860 – Organizational Management Capstone, February 13, 2002.



### 6.3.1 Basis

As noted, the calculator is based on the Continuous Review QR Model which determines the appropriate Supermarket inventory level for a given part based on the average part processing time (lead time), daily demand for that part and the variability in this daily demand. Reiterating the QR Model formula:

$$R = L\mu + z\sigma\sqrt{L}$$

For this Calculator

R = Minimum Inventory

$\mu$  = Average Daily Demand

L = Average Lead Time (processing time for that part from start to Supermarket)

z = service level factor (determined by percentage of time will meet customer demand)

R + one-shift of demand = Maximum Inventory

I will point out that since the batch sizes per part are already established at the plant, there was no need to develop an EOQ = Q. Normally, in the QR Model, the minimum inventory level is set at R and the maximum is set at R+Q. In discussions with management, however, they preferred to base the maximum increment in terms of one shift of inventory. Therefore, the calculator establishes a Supermarket maximum equal to the minimum plus one shift (eight hours) of demand.

In addition, I considered whether I could identify a typical standard deviation depending on the type of variation in the part (common, color, or family), however, I did not observe such a trend and so did not pursue this further.

### 6.3.2 Purpose

The overall purpose of the Supermarket Calculators is to establish initial minimum and maximum Supermarket inventory levels for each of the in-house produced components (parts). Predictably, this will be most valuable:

1. In preparation for a new model year
2. When production demand changes significantly
3. When a part process changes significantly

Based on the fact that the sequenced schedule is managed in quarterly blocks and, historically, there are some seasonal impacts to demand variability, I would recommend that the calculators be revisited on a quarterly basis or as otherwise needed. I have emphasized in the 'Instructions to User' that the intent of the calculator is to take a 'first cut' at how much inventory will be needed. This is indeed a first step after which incremental adjustments should be made based on real observations. For example, if stock-outs are observed to occur relatively frequently despite normal operations (e.g., no major unplanned downtime) the Supermarket size should be increased and the source of variability that is not being captured should be identified and quantified, if possible. Similarly, if excess inventory is continually observed, the area Supervisor may choose to gradually reduce the Supermarket size. In this case, average lead time may have been overestimated.

### 6.3.3 Right-Size Supermarket Calculator

In addition to sizing the finished goods Supermarket, the Right-Size Supermarket Calculator could also be used to size intermediate Supermarkets or buffers between any two points along a component process. For example, if you wanted to size a Supermarket located at the end of the Green Side of Transmission (the first half of the Transmission part process just before Heat Treat), the 'Average Lead Time' used in the calculator would include only the Green Side processing time (not Heat Treat or Finish Side). If such

an intermediate Supermarket was established for the Green Side, then the Finish Side (the second half of the Transmission part process after Heat Treat) Supermarket would only need to accommodate the Average Lead Time from Heat Treat to the actual finished goods Supermarket.

Establishing intermediate Supermarket locations for long lead time component processes is one strategy that can lead to reduction in the amount of inventory needed in the finished goods Supermarket. An example of the Right-Size Supermarket Calculator interface is shown below in Figure 6-1. A sample calculation is shown for a part that has average daily demand of 320 powertrain units (1 part per powertrain unit), an average lead time of 12 hours, a daily demand standard deviation of 17 parts and standard load size of 10 parts. Other aspects such as machine uptime and scrap levels are also included below.

<b>RIGHT-SIZE SUPERMARKET CALCULATOR</b>		
*** This calculator has some limitations (described on Instructions & Notes tab) and should only be considered a STARTING POINT/ GUIDE – not an absolute and firm sizing of the Supermarket ***		
<b>Part Information (enter information in all yellow cells - white cells are automatically calculated)</b>		
Part Number	12345	
Part Name	A	
Part Starting Location	Machine A	
Supermarket Location	Machine Z	
Average Daily Demand (Powertrain Units)	320	
Number of Parts per Powertrain Unit	1	
Average Lead Time (hours) per part from Part Starting Location to Supermarket Location given above:	12	
Number of hours part is run per day:	24	
Average Lead Time (days) per unit	0.50	
Standard Deviation of Daily Demand (# parts)	17.00	
Standard Load Size (# parts)	10	
Scrap Fallout (%)	3%	
Machine Uptime (%)	85%	
Desired Service Level (%)	99%	
Service Level Factor	2.33	
	<b>Normal Stock</b>	<b>Variable Stock</b>
# Parts	195	29
# Loads	20	3
	<b>Supermarket MINIMUM</b>	<b>Supermarket MAXIMUM</b>
# Parts	224	331
# Loads	23	34
Hours of Inventory	17	25
# Shifts Covered	2	3

**FIGURE 6-1 – Right-Size Supermarket Calculator**

As shown above, the Right-Size Supermarket Calculator returns the Min/Max number of parts, number of loads as well as corresponding hours of inventory and number of shifts covered by the inventory level.

### 6.3.4 Lead Time Reduction Supermarket Calculator

The idea behind the Lead Time Reduction Supermarket Calculator is to give the user a way to determine if reducing the part processing time (lead time) will significantly reduce the needed Supermarket inventory levels. In general, the most considerable inventory reductions will happen for part processes in which the variability in demand is somewhat high. See Figure 6-2 below for the illustrated example. In this calculator, you would enter a revised, reduced processing lead time to determine how much the Supermarket inventory would be reduced. The calculator provides the percent reduction from the current inventory level as well as revised Supermarket minimum and maximum levels.

LEAD TIME REDUCTION SUPERMARKET CALCULATOR			
<i>How much does a reduction in Lead Time reduce inventory levels given current run times?</i>			
Current Average Lead Time (hours) per part from Part Starting Location to Supermarket Location given	12		
Suggest New Reduced Average Lead Time (hours):	10		
Average Lead Time (days) per unit	0.42		
% Reduction of Inventory	0.02		
% Reduction of Inventory from Current	-16%		
		<b>Normal Stock</b>	<b>Variable Stock</b>
# Parts		162	26
# Loads		17	3
		<b>Supermarket MINIMUM</b>	<b>Supermarket MAXIMUM</b>
# Parts		188	295
# Loads		19	30

**FIGURE 6-2 – Lead Time Reduction Supermarket Calculator**

### 6.3.5 Planned Downtime Bank Calculator

At times, there is planned process downtime such as for machine moves or major preventative maintenance. Under these circumstances, the affected component group would want to know how much inventory they should put aside to cover Assembly demand while they are down. For this case, I included a Planned Downtime Bank Calculator. For this calculator, the user enters the expected downtime (in hours) and the calculator provides the amount of inventory that will cover demand during that period. Figure 6-3 below illustrates an example for this calculator.

DOWNTIME BANK CALCULATOR			
<i>What size inventory bank is needed due to High Machine Downtime or Planned Downtime Period?</i>			
Is there a point in this part's process with high machine downtime?	Yes		
Machine Uptime (%):	85%		
Mean Time to Repair or Expected Downtime (hours):	1.5		
Mean Time to Repair or Expected Downtime (days):	0.06		
		<b>Downtime Bank</b>	
		# Parts	25
		# Loads	3

**FIGURE 6-3 – Planned Downtime Bank Calculator**

### 6.3.6 Calculator Instructions

In addition to the information discussed in terms of the purpose and usage of the calculators, there are instructions included in the Supermarket Calculator file that provide guidance to users for data entry. These notes are as follow:

- Enter data in all yellow cells. Do not attempt to include data in white cells; these cells will calculate your desired inventory levels and are locked to prevent accidental user overwrite.
- Instructional notes are provided for each yellow cell requiring data entry. As you wave the cursor over these cells, a comment box will appear explaining, in more detail, the data required in that cell. All yellow cells must be completed before calculation will be complete.
- Model Year 06 Average Daily Demand and Standard Deviation of Daily Demand are provided on a separate sheet/tab within this file.
- Forecasted Model Year 07 Average Daily Demand and Standard Deviation of Daily Demand are also provided, but are based on data available as of December 2005; these numbers should be revised based on current data available from Scheduling.

### 6.3.7 Limitations of the Calculators

There are several limitations of the calculators and these limitations are explicitly highlighted within the 'Instructions to User' page provided with the Calculators. A summary of limitations are as follows:

- Low confidence on lead time data for parts that have highly variable queue time events within their process (e.g., Transmission parts with Heat Treat)
- Lead time data used is an anecdotal average and does not account for any 'real' high variability in lead time. In general, there is a lack of 'real' lead time data.
- The Calculators should only be used as starting point for inventory levels (e.g., model year start) and for guidance for decision making. Calculated inventories may need to be adjusted based on real observations and changing process needs.
- The established batch sizes may or may not be the most economical size for the current demand scheme. Because partial batches cannot be ordered, this could increase the calculated inventory volumes which round-up to the nearest full batch size.

### 6.3.8 Success Measured Against Tool Goals

*"We are actually using "the calculator" for some of the '07 Tranny parts."*

- Email from the 3WA PTO Product Plant Manager for Component Groups (Feb 2006)

Given the inherent limitations I encountered, I believe I met the major goals set for this inventory calculation tool. With basic instruction, users have demonstrated and concurred that the tool is easy and straightforward to use and, for the most part, asks for data that is easily accessible. I say, 'for the most part', because getting revised daily demand standard deviations may present difficulties if many different component groups ask for these data at many different times from the Scheduler. To remedy this, I would recommend scheduling a quarterly re-evaluation event performed by the Scheduler. The data needed to determine these standard deviations will already be available to the Scheduler as it is also used in the demand planning aspect of the Scheduler's job. The incremental effort of calculating standard deviations from this data is relatively minimal, provided it is done only four times per year (rather than upon random request).

In terms of the interface of the tool, most people have expressed that it was visually pleasing and clear. I had a few suggestions such as to make the font larger to make text/numbers easier to see, and I have made this adjustment for the final version.

The one thing I would have done additionally while I was present at 3WA PTO was to better market the tool to potential users to help develop it into a standard tool. I ran out of time before I could complete market saturation. However, I did leave the tool with others I worked with in the Continuous Improvement group and they will continue to suggest the use of the Calculators to the component groups. Based on the initial quote above, I at least know someone is using it.

## 6.4 Visual Supermarkets

The next step to better inventory management is making it more visual. As I discussed in Section 4.1, there is currently a lot of part counting in preparation for the production meeting to determine how many parts are in the finished goods Supermarket at the end of each shift and if that amount is above or below the minimum quantity required. Because the component area Supervisors are already overloaded (in terms of being incredibly busy), I suspect they would welcome not having to count parts, provided they could trust the alternative.

Once Supermarkets have been right-sized and enough time has passed to demonstrate that the inventory level is appropriate, the Supermarket itself could be used as the signal to the upstream process to indicate when they need to process more parts. In this way, the Supermarkets themselves can be used as a Pull system without Pull Cards. Visual Green (enough inventory) and Red (low on inventory) zones can be established to communicate immediate inventory status to the upstream process. Similarly, each upstream process in line can take production cues from the subsequent process.

This approach depends heavily on there being enough space on the floor to accommodate the right-sized Supermarket capacity. If floor space is scarce, one way to make the Supermarket physically smaller without reducing the required number of loads in the Supermarket would be to have more frequent pick-ups by material handlers. Basically, the inventory would be turned faster and sit for a shorter period of time, eliminating the need for as much space occupation. This, of course, presents additional logistics challenges since the material handlers are already on relatively constrained delivery patterns and increasing their stops at any given location would further complicate their routes.

An additional use of a visual Supermarket would be to place a right-sized Supermarket (complete with the Red/Green zones suggested) after a shared resource process. This set-up could help the operator to make decisions about which part to make next (based on what is low/Red) and see when there is enough of a given part (ok/Green). This would also give better flow visibility to the more complex flow processes such as in Transmission. Having visual cues to understand the current state of the system would be invaluable to newer Supervisors who do not have the benefit of 20 years of experience like many of the veterans.

Finally, freeing up Supervisor time by not counting parts or spending less time determining the status of the system could free them up to work on more continuous improvement projects. The visual Supermarket idea should certainly be marketed as a potential time saver to get buy-in from component group Management and Supervisors – all people who are extremely time constrained.

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## 7 Data Driven Decision Making

In my pursuit to determine what data would be easily accessible for component group and area Supervisors for use in the Supermarket Calculators, it became clear to me that there is a lack of manufacturing data that is recorded continuously or on a regular basis throughout the day. Except for the demand data, the remaining data used for in the Calculator is largely anecdotal/ based on experience. This was an overall concern to me because, as mentioned earlier, solutions are only as good as the data built into them. Lack of data that truly represents what is really happening on the floor can only lead to sub-par solutions that do not meet the real goals and needs of the plant.

In this section I will mention some of the data that I could not access and why I thought this data would have been useful. I will also identify the general incentives and potential benefits that 3WA should consider in terms of becoming more data driven. Finally, I will mention some opportunities to use such data to better align plant and people incentives.

### 7.1 Lack of Data

While conducting data mining related to development of the Supermarket Calculators, I determined that there is quite a bit of data that is largely based on experience and recollection of the area Supervisors or operators. This is in line with the very tribal knowledge based culture of 3WA, which will be discussed in greater detail in Chapter 8. In general, limited data are recorded on a continuous or consistent basis. Data that are not recorded that would be valuable include:

- Continuous process lead times
- Machine downtime
- Scrap amounts
- Queuing time (where applicable and frequent)
- Change-over/set-up times

For example, when I inquired with each component group lead and area Supervisor about the lead time for each of the in-house produced parts, the answer was always something like: “It takes about 10 hours”. When I asked if day-to-day parts processing times were recorded, the answer was “No”.

In addition to data related to the Supermarket Calculators, there are other data that I could not access because they were not regularly recorded or were not in a readily useable form, for example:

- An inventory of what is in Repair at any given time
- Supermarket levels per shift – electronic/historical

### 7.2 Incentives for Becoming More Data Driven

To achieve a more stable and standardized process that will lead to true continuous improvement, 3WA PTO must have a way to identify and understand the current state so that they know how far they are from the desired state. Building data into everyday decision making can help to:

- **Save Time** - avoid individual manual collection
- **Provide more accurate operations decisions** – reduce inventory through more exact understanding of needs
- **Identify hidden trends and interdependencies** – collection of ongoing and historical inventory levels per component and experimenting with regression analysis

- **Develop standard tools** – tools like the Supermarket Calculators can be used by all if everyone has easy access to the right data
- **Improve efficient knowledge sharing** – when data is easily available to all, then informal information sharing, which is generally inefficient and incomplete, can be limited to non-objective and more meaningful discussions (e.g., talk about something other than parts levels in the production meeting).
- **Improve discipline/accountability** – this follows the idea that “*people don’t do what you expect, they do what you inspect*”<sup>19</sup>. If people’s statements and work can be easily evaluated based on real, available data, then they will feel more accountable for what they do and say and from this better discipline follows.

### 7.3 Alignment of Incentives

Data can be a very powerful tool, but using it to produce desired results can be a challenge. This relates to making sure that metrics incentivize the right behavior. This leads to careful consideration of what is being measured.

For example, current 3WA PTO production goals are based on producing a certain number of units per shift, and per day. This goal encourages overproduction or building too far ahead in the schedule on occasions where many units have been Cut out of the planned schedule and Assembly will build into the next day’s schedule. As discussed earlier, whenever Assembly production deviates greatly from the planned schedule (produces more system variability than expected), negative effects wave through the plant.

Similarly, the current method of determining cost per unit based on volume (numbers of units) also encourages overproduction so that costs are spread out over more units making the apparent cost per unit lower. Eventually, when exceeding the production goal is consistently rewarded, a ‘hero’ mentality emerges and everyone wants to do whatever they can to ‘beat yesterday’s numbers’.

In order to remedy this tendency to ‘overproduce’, 3WA PTO should develop a schedule quality metric (e.g., maximum schedule deviations) that is as equally scrutinized as unit production numbers. In addition, this metric should be designed to distinguish between types of schedule deviations (e.g., Cut for high runner vs. Cut for a low runner) and estimate costs of these deviations to counteract the apparent ‘cost savings’ from overproducing.

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<sup>19</sup> Gerstner, Louis V. Who Says Elephants Can’t Dance: Inside IBM’s Historic Turnaround. November 2002.



## 8 Organizational Change and Strategy

3WA has experienced 20 years of continuing growth both in terms of revenue and production volume. In addition, they enjoy a strong, relationship-based, tribal knowledge anchored culture that is well versed and comfortable in this era of continuing company success. Despite this environment of company success, it is clear that the competition is gaining ground in the market as 3WA is growing at a slower pace than the overall market and are higher cost than their competition.

The challenge then is: *How do you create change and innovation in an organization where there is no clear sense of urgency?* Many segments of the organization are feeling ‘fat and happy’ while respected senior staff are great at ‘getting things done’ despite a system that is neither standardized nor stable – this is a dangerous combination. As Mr. Chris Magee, Professor of Mechanical Engineering and Engineering Systems Design at the Massachusetts Institute of Technology (MIT), astutely observed: *“In an environment that has seen a lot of success...you need a burning platform to make an impact and create change.”* At the same time, creating a sense of urgency can ironically backfire when we overfocus on the point of urgency to ‘correct the problem’ rather than allowing this urgency to permeate and create a greater sense of organizational change momentum.

During my stay at 3WA PTO, I did find many people who were not only well aware of the need for organizational change, but also recognized how difficult this change can be and why history is one of the biggest obstacles in a tribal knowledge based culture. One of the 3WA PTO Engineers summed this up best:

*“For the people who have been around for a long time, they have seen things change – then change back – then change back to the way things were before...this creates the attitude of ‘Not this again’ or ‘It didn’t work last time, so why should I expect this to work now?’ ...the factor that doesn’t get considered when these statements are made is: ‘How are the manufacturing system requirements different today? Volume/mix? Some of this change/change back may be happening because of lost knowledge, but other times, it could be happening because different manufacturing approaches/systems may need to change with current production. We need to make sure we are asking the right questions: Why are we returning to this idea and how will we not make the same mistakes twice?’”*

In this section, I will discuss three issues that all relate to organizational change and strategy: 1) Possible strategies for ‘Pulling’ rather than ‘Pushing’ change in the 3WA PTO environment; 2) The implications on the organization’s ability to change when anchored in a tribal knowledge based culture, and 3) Further challenges ahead as 3WA approaches the ‘demographic cliff’. To illustrate the current situation and possible future strategies for change, I will borrow from my observations and observations of others at 3WA PTO.

### 8.1 True Change – Pulling Change

In the interest of a project that started with a ‘Pull-to-Assembly’ initiative, I found the metaphor of ‘Pulling Change’ created by Janice A. Klein in her book “True Change”<sup>20</sup> quite appropriate to my research project. I will use the framework she developed to suggest some approaches regarding how 3WA PTO might effectively approach change by ‘pulling’ change in their organization. Klein suggests three basic concepts to execute ‘true change’:

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<sup>20</sup> Klein, Janice A. True Change: How Outsiders on the Inside Get Things Done in Organizations. 2004.

1. True change occurs from within – external consultants can recommend, but cannot operationalize change
2. Pushed ideas are almost always resisted.
3. The organization must create a critical mass of ‘outsiders on the inside’.

I will treat each of these briefly as it applies to my project and observations at 3WA PTO.

### 8.1.1 Change Occurs from Within

Knowing that real operationalized change must occur from within left me at a perceived disadvantage as a research intern from MIT. However, I was not discouraged – this was my expectation going into this situation. I was a consulting engineer my last nine years of work life and understood that the role of a consultant (or in this case an intern) is not necessarily to create change, but to seek out the root causes of problems that would otherwise be masked by insider cultural assumptions and mental models. In such a role, you can be the impetus for change, but unlikely the creator of the change.

### 8.1.2 Pushed Ideas are Resisted

The idea that pushed ideas are resisted certainly rang true at 3WA PTO. Not only was this evident, but I found that most of the workers on the floor were so ‘wise’ to pushed change that they had developed a tried and true technique to avoid change that surpassed resistance. I will call this technique ‘temporary compliance’ followed by ‘return to the status quo’. The following was an area Supervisor’s response to me when I asked about how he felt about a possible adjustment to their process:

*“People come in here wanting to make their mark and try to make quick changes and try to do things too fast. I think people on the floor don’t respond to change for two reasons: 1) People try to make changes without a good foundation/reason for the change (other than to make them look good and promotable) and 2) We all know that there is quick turnover of people in different positions, so in the back of everyone’s mind is that they can just wait it out and sooner or later this person will go away [move on to another position/another location].”*

This lead me to the idea that anyone resembling a ‘Change Champion’ has no chance at creating change in this organization. 3WA is known for quick rotations for their ‘fast-trackers’ (aka – blue chippers, or pick your favorite moniker for people who are expected to climb the corporate ladder quickly). These people are in and out of an area of the organization in eight months to a year. Everyone knows this (thus, the above quote). These ‘fast-trackers’ would be better served if they approached each assignment as an ‘outsider on the inside’ rather than a Change Champion. A period of less than a year is not likely enough to earn the kind of credibility needed in this organization to leverage a change Pull. This organization currently values years of wisdom over bright ideas (more on this in the next section), so the outsider on the inside must perform the service of identifying gaps between the current view and the problem root cause and then pass the solution onto someone who has existing organizational credibility and desire to follow through.



As stated, real opportunities to Pull change result from identifying a gap between the current view of a challenge and the root cause of the challenge. I believe I was able to do this for my project by identifying that before ‘Pull-to-Assembly’ could be executed effectively, the production system really needed more standardization and stability. To become more stable was to work toward elimination of schedule deviations and to eliminate schedule deviations meant that the in-house inventory management system needed standardization and improvement. While this seems clear to me now, it took me over three months in the organization and much time on the factory floor to realize this.

I can understand how other parts of the organization were running full steam ahead on implementing plant-wide ‘Pull-to-Assembly’ because that is what the organization and management was telling them to do. They had no incentive or real power to either question or change this directive. As an outsider/intern, questioning was my ‘job’ and so I was able to do so with low or no risk and was able to identify this problem vs. root cause.

### **8.1.3 Create a Critical Mass of ‘Outsiders on the Inside’**

Klein defines ‘outsiders on the inside’ as people who live inside the organization (employees), understand the cultural assumptions and have established credibility, but who are able to see beyond the cultural mental models and observe challenges like an outsider. These are “people who see daily challenges ripe for applying alternative assumptions to solve critical problems.”<sup>21</sup>

Even in an organization where most employees live, eat and breath the culture, I believe 3WA still has portions of their existing organizational structure that will allow great opportunities for maintaining outsiders on the inside. I have two suggestions for 3WA: one for 3WA PTO specifically, and one for 3WA as a whole. The following groups within the organization are ripe for developing and preserving outsiders on the inside:

1. *3WA PTO Continuous Improvement Group* – Members of the Continuous Improvement Group already serve very cross-functional roles with a charter of identifying and supporting execution of continuous improvement projects through all areas of the plant. This group, by design, maintains a more high-level, big picture view of the plant and is more focused on strategic projects, such as capacity planning, than the tactical day-to-day production.
2. *3WA Leadership Development Program (LDP)* – This is a rotational leadership program where participants are given three short term assignments (~ 1 year in length) that require them to work in various areas in the 3WA organization as a whole to gain an understanding of the interworkings and interconnections in the company. Informally, these people are often called “fast-trackers”. Many of the LDP projects are cross-organizational and so are primed with opportunities to identify gaps between the identified needed challenge and root cause.

Both of these groups should work to align themselves with the highly experienced ‘old-timers’ in the system to get the deepest understanding of the potential cultural challenges they will face when promoting new ideas. I term these ‘old-timers’ The Boons, and describe the role of The Boons later in Section 8.2.

There are two critical aspects to maintaining outsiders on the inside in an organization. First, these people must understand the duality of their role so they are cognizant not to fall too deeply into the insider portion and lose their outsider perspective. The dual-nature of these people are what makes them so valuable to the organization. Second, they must also understand that their role will often be to identify a

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<sup>21</sup> Klein, p. 14.

broader problem, possibly help with a plan to remedy the problem, but specifically not to attempt to solve the problem themselves. Problems identified by outsiders on the inside are best left to a future entrant into that group or existing insiders in the group. The insiders will have better credibility to make the change a Pull rather than a Push.

#### 8.1.4 Other Observations of ‘Pulling Change’ at 3WA PTO

*“The new definition of leadership lay in creating and sustaining an environment in which people work together toward the achievement of common goals, and not because they have to, but because they want to.”*

-Quote by former 3WA CEO, President, CFO, and COO<sup>22</sup>

There are a few other lessons I learned at 3WA PTO during my project that I will take away from this experience. The first is about the leadership and its role in Pulling change – pro and con examples. The second is about understanding the organizational power structure and not opposing it. The third is about the importance of initial successes when trying to implement a change.

##### 8.1.4.1 Importance of Leadership in Pulling Change – Pro & Con

- ***Con...not the right kind of leadership support*** – This refers to both Supervisors at Powdercoat as well as higher level Managers. Although there was plenty of verbal support and head-nodding from both sources of leadership, the immediate and proximate reinforcement of the Pull system was not there. Both Powdercoat Supervisors had worked at the plant for more than 20 years and, under typical conditions, were able to manage Powdercoat well without the Pull system. Although they both put forth physical effort to support the implementation (window dressing?), their actions did not generally reinforce the necessary discipline of the Pull concept.
- ***Con...lack of discipline and taking a cue from leadership*** – *This example is also from the attempted implementation of a Pull system at Powdercoat.* Because the Supervisors were not always making production decisions based on the Pull system, workers took this as a cue that using the system was optional.
- ***Pro...Leadership lead to increased communication between Sequencing/Assembly and Scheduling*** – The most surprising observation I made during my work with the Sequencers and Schedulers was that these two groups of people did not communicate despite the fact that they are so deeply connected by the sequenced production schedule. A major source of frustration with both groups was that there was no visibility of the difficulties or reasons for actions of the other group. As described in Section 3.5.1, after bringing this communication gap to the attention of the Assembly Plant Manager, regular half-hour morning meetings including all parties were established to allow joint problem solving and regular communication was established.

##### 8.1.4.2 Importance of Power in Pulling Change

- ***Power struggle and resistance to change*** – *Another observation surrounding the moderate success of the Pull implementation at Powdercoat.* Previous to implementation of the Pull system at Powdercoat, decisions about what to produce next were made by a specific lead worker per shift. Under the Pull system, however, these decisions are basically made by the status of the

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<sup>22</sup> Former 3WA CEO, President, CFO, COO, March/April 2001, “The Leadership Journey at [3WA], “Corporate University Review, Vol. 9, Issue 2, pl+.

cards on the Pull board. In this way, the Pull system took away the perceived power in knowledge of the lead worker. It was observed that these lead workers, in general, were not supporters of (and actually tended to sabotage) the new Pull system, likely because it removed some of their power and their ability to garner respect from co-workers.

### 8.1.4.3 Importance of Initial Success in Pulling Change

*“When creating innovation, start where conditions are optimal. There is a temptation to go for checkmate right off the bat. Go first where success is most likely.”*

- Jonathan Byrnes in Supply Chain Case Studies Class, February 27, 2006

A final observation is best summed up by another quote from a worker in the Lowers component group who anticipated that the Pull system would be implemented in his group next:

*“You continue to hear ‘Pull Doesn’t Work’ and this attitude is contagious. People know that they are trying to implement ‘Pull’ at Powdercoat and at the same time, Powdercoat is not running well and so many people think that means that the Pull system is causing the poor performance.”*

This comment speaks to the importance of starting a new implementation at a location that is a guaranteed success rather than the one that is the most challenging to go for the small wins first. In my opinion, Powdercoat is by far the most challenging implementation and should have been attempted only after some initial, visible success in another area where success was more certain.

## 8.2 Tribal Knowledge Culture

*“I agree that the tribal knowledge culture is at the root of a lot of resistance. Not only does change require folks to change behaviors and develop new knowledge, but it also shifts power from the tribal knowledge holders to the process knowledge keepers. That’s a really big thing in tacit knowledge systems.”*

- Email response from Jan Klein, MIT Professor of Leadership and Organizational Change, August 10, 2005

As alluded to earlier, 3WA is over 100 years old and has been built on a tribal knowledge foundation. In this environment, information and norms have been established and passed down over time and so, on the whole, there is no real ‘operations manual’ for how things get done there. Management recognizes that as 3WA grows, it is getting harder and harder to run the business based on tribal knowledge. And management is not the only group that recognizes the threat of running this way. The following quote was from a worker on the floor at 3WA PTO commenting why their area was getting by even though they were not operating as the new system specified:

*“It’s the tribal knowledge and deep experience that is getting things done despite the fact that the system is not running as it should.”<sup>23</sup>*

The marketing department is dealing with this as well. At a breakfast presentation on July 13, 2005 by the VP of 3WA Marketing, Joan Smith<sup>24</sup> expressed that the things that 3WA traditionalists always say

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<sup>23</sup> Conversation with worker in powertrain Final Sequencing, August 4, 2005.

<sup>24</sup> Name disguised.

‘no’ to, with respect to marketing strategies, could be holding back market growth into new, non-traditional areas. The observations of this Marketing VP effectively demonstrate the relationship between the very traditionalist leanings of a tribal knowledge based culture and the organization’s resistance to change. It is understandable that people may feel that keeping tradition alive means not changing. And so the question must be asked: *How do you Pull change in a culture that is so deeply imbedded in tradition?*

Because I believe that 3WA will not be able to continue to grow without changing away from the pure tribal knowledge approach, I think they must search to understand the most effective way to shift from a very tacit, tribal knowledge valued culture to a process knowledge value culture. The key to this transition lies in the very people who grew-up through the organization; and many will not be around much longer (see next section, Demographic cliff).

These are the most senior people in the organization who have been at this company for a very long time (20+ years) and have their ‘way’ of doing things (Rule of Thumb, personal methods that work for them). Many of these people cling to their ‘old’ methods despite the fact that processes and manufacturing methods are changing to keep up with continued growth. In addition, these are also the people who less senior people look to for direction. Inefficiencies grow out of this conflict between ‘the way it’s always been done’ and the new, standardized way it needs to be done to allow growth. I contend that these senior people, who I will group into ‘The Banes’ and ‘The Boons’, are the keys to the immediate success or failure of 3WA’s future change.

The ‘Banes to Change’ are those who refuse to try new methods and will always revert to ‘their way’. I observed a clear example of this in the flywheels area. In that area, a Pull system limited to one portion of their operation had been implemented by a young, motivated area Supervisor and the system was working quite nicely. Because this system proved to be a help to the operators, it was well accepted and happily executed day-in-day out. Somewhere during the middle of my stay at 3WA, there was a change of the guard in the flywheels area. The young area Supervisor was promoted to a position in materials and a seasoned veteran returned to the flywheels area. This veteran ran flywheels previously and had a clear plan of how she wanted it run – and that did not include the Pull system. Seemingly overnight, the flywheels Pull system disappeared and the area was then managed closely by the veteran Supervisor just as she had successfully done in the past – I call this veteran a Bane to Change.

In contrast, you have the ‘Boons to Change’. The Boons are those senior people who have been willing to change and grow with the company and are among the most well respected change leaders. These are the people who everyone follows and so it is quite easy for them to Pull change – lead change. One of the veteran engineers I worked with in the Continuous Improvement Group was exactly one of these Boons. He was the ‘go-to-guy’ on every occasion that required an innovative solution. He continued to deliver new solutions for new situations. To align myself with him, I noticed that he usually arrived at work at least an hour earlier in the morning than most of the other salaried staff. I made a point to also arrive early every now and then to present some ideas to him. More often than not, I realized through our discussion that I was not accounting for some factors that would be keys to an effective solution; this is where the tribal knowledge really showed itself. The Boons will be one aspect driving success for any outsiders on the inside at 3WA, specifically.

For 3WA to grow from their tribal knowledge culture into a more effective, process knowledge organization, they must identify both The Banes and The Boons. They should leverage the Boons against the Banes. In an experienced based culture like 3WA, the only way to question the assumptions of The Banes is to ally with The Boons to do this. In addition, 3WA should make sure The Boons are mentoring the incoming ‘best and brightest’ in the organization so that their valuable knowledge is not lost; in this

way The Boons act as 'legacy coaches'. This idea will be explored further in the next section which discusses the impending demographic cliff.

### **8.3 Demographic Cliff**

*"Within half a dozen years, baby boomers—some 76 million people, more than a quarter of all Americans—will start hitting their mid-sixties and contemplate retirement. And why not? Long-standing human resource practice is to invest heavily in youth and push out older workers. But this must change—and so must public policy—or companies will find themselves running off a demographic cliff as baby boomers age."*<sup>25</sup>

- Ken Dychtwald, et. al. "It's Time to Retire Retirement" (March 2004)

In companies where a large portion of the workforce is older, we say that they are "managing against the demographic cliff". There is certainly an opposing school of thought that contends that because people are living longer and retiring later, the threat of an aging workforce is not as bad as it appears. Regardless, understanding this issue and how it may relate to ones company is essential; better to plan for a catastrophe that never happens than to be taken by surprise. This section will explore the implications of the demographic cliff including the potential for lost knowledge as well as general organizational strategies to retain knowledge, effectively transfer knowledge and build an infrastructure for continued knowledge sharing.

After laying this groundwork, I will discuss the demographic cliff and the my interpretation of the threat to 3WA, specifically. In addition, in the context of 3WA's existing environment, I will propose possible future strategies that could be implemented at 3WA to preserve existing knowledge while building the organizational infrastructure and culture for future knowledge sharing and retention.

#### **8.3.1 The Demographic Cliff and Impacts to Organizational Knowledge**

By 2010, 25% of the current working U.S. population will reach retirement. This translates into a worker shortage that is expected to be 10 million by that time. Between now and then, the number of employees aged 55 and older is expected to increase by 49.3%.<sup>26</sup> Based on these statistics, concerns regarding demographic changes coupled with generational shifts are high on the list of companies whose demographics mirror the U.S. as a whole. This scenario is most prevalent in traditional U.S. manufacturing companies such as automotive, aerospace and other mature product manufacturers and so my evaluation and analysis will focus heavily on such industries with predominantly older workforces, much like at 3WA.

##### **8.3.1.1 What is the Demographic Cliff?**

The demographic cliff is essentially the anticipated shortage of labor which coincides with the retirement of baby boomers. The post World War II baby boomers are almost double the size of Generation-X (the subsequent generation) and they grew through the workforce during a time of tremendous growth and technological development. Table 8-1 below shows the generational profiles from baby boomer to present.

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<sup>25</sup> Dychtwald, Ken, Tamara Erickson, and Bob Morison. "It's Time To Retire Retirement." Harvard Business Review. March 2004.

<sup>26</sup> Bureau of Labor Statistics – online December 2005.

<b>GENERATION</b>	<b>RANGE OF YEARS</b>	<b>SIZE OF GROUP</b>	<b>CURRENT AGE RANGE (as of 2006)</b>
<b>Baby Boomers</b>	1946 to 1964	76 million	42-60
<b>Generation-X</b>	1965 to 1980	46 million	26-41
<b>Generation-Y (aka Millennials, NetGeneration)</b>	1981 to 1999	76 million	7-25
<b>Generation-Next</b>	2000 to ?	?	6 and under

**TABLE 8-1 – Profile of Generations from Baby Boomer to Present**

Table 8-1 clearly shows the disparity between the size of the baby boomers generation versus Generation-X and the cyclic nature of generational population expansion and contraction. The fact that there will be an apparent shortage of workers as baby boomers retire is only part of the problem – the real developing problem is a shortage of qualified, skilled workers. The exodus of baby boomers from the workforce, a negative stereotype of manufacturing and a drop in the number of U.S. students pursuing technical or engineering degrees are fueling this problem. This disparity and the structure of the current knowledge economy have created three major implications with respect to the demographic cliff:

1. ***Today’s knowledge economy is difficult to replicate*** – There is increased complexity of knowledge in a technically advanced society that makes knowledge transfer more difficult. In addition, most companies do not currently have effective knowledge retention systems in-place.
2. ***Shrinking pool of highly skilled younger workers to replace retirees*** – Generation-X (Gen-X) has traditionally been more technology focused and so there are fewer Gen-Xers pursuing the type of training and skills needed in manufacturing. Therefore, not only are the retired baby boomers (76 million) going to leave a substantially larger gap than the smaller Gen-X segment (46 million) can fill, but an even smaller fraction of these Gen-Xers will be qualified (or interested) to fill these gaps.
3. ***Scarce resources may come at a price premium and impact company competitiveness*** – As all manufacturing companies facing the demographic cliff scramble to replace retirees, they will be competing for the same scarce resource – those Gen-Xers who have chosen to pursue skilled manufacturing jobs. Assuming a free market, these resources should have higher seller power that may allow them to demand higher wages than the current standard. A significant rise in wage rates would surely have implications on a manufacture’s ability to compete on cost, particularly in more labor intensive industries and in light of recent increased international competition based on labor.

These are not future issues – the impacts are being felt right now. A recent article in the *New York Times* (November 22, 2005)<sup>27</sup> discusses this very matter. According to an industry study released just prior to the writing of an article, “more than 80 percent of U.S. manufacturers say they cannot find enough qualified workers to meet customer demands”. The article continues:

*“While some 3.4 million factory jobs have been lost since 1998, the National Association of Manufacturers said employers are now struggling to find enough high-skilled machinists,*

<sup>27</sup> Reuters. “Skills Shortage Plagues Manufacturers.” *The New York Times*. November 22, 2005.



*technicians and engineers to keep production lines humming. Of more than 800 manufacturers surveyed, 13 percent reported a severe shortage of qualified workers, while 68 percent experienced a moderate shortage. The survey exposes a widening gap between the dwindling supply of skilled workers in America and the growing technical demands of the modern manufacturing workplace.”*

### **8.3.1.2 Lost Knowledge**

The current organizational systems in most companies are not designed to capture and retain knowledge. Instead, most structures rely on the existence of the knowledge-keeper to retain and to share or pass-on knowledge; few actually do. Examples of types of lost knowledge include ‘old’ designs for legacy equipment or systems, expert knowledge in a particular area, and relationships with inside or outside decision makers. In addition, it is important to keep in mind that there are generally four types of company knowledge:

1. Human knowledge – a skill or ability
2. Social knowledge – relationships, social capital, network, collaboration
3. Cultural knowledge – how things are done, what to do to fit-in
4. Structured knowledge – systems, technical (explicit/tacit), processes, tools, routines, etc.

Throughout this section, the discussion of knowledge can mean any and all of these types. You will note that some of these knowledge types are experiential (social, cultural) and some can be learned (human, structured). The loss of experiential type knowledge will, in general, be much more difficult to recover once it is gone. The rest of this section will discuss the most common barriers companies face with regard to knowledge retention and then follow with the primary implications of lost knowledge.

#### **8.3.1.2.1 Barriers to Knowledge Retention**

In general, barriers to knowledge relate to how organizations currently manage knowledge. Even though information management has become advanced in the last decade, most organizations have not incorporated systematic ways to identify the knowledge in their companies and determine how to most effectively share that knowledge. The following are the predominant knowledge retention barriers organizations are dealing with today<sup>28</sup>:

1. ***Hidden costs of lost knowledge*** – In order for most managers to recognize the potential impact of a threat to their business, they must be able to identify clear cost implications. The impact of lost knowledge, however, is often hidden in the consequences of the missing knowledge (i.e., inefficiencies, unexpected skills gaps) and not directly attributed to the missing knowledge.
2. ***Lack of awareness of vulnerability*** – Particularly in large organizations, it is difficult for managers to identify where they are vulnerable to lost knowledge. That is, they may be able to anticipate who will be retiring or leaving the company soon, but they may not have a complete understanding of the skills and information these people will take with them. To capture this knowledge, managers must be able to anticipate the knowledge and skill gaps.
3. ***Lack of ownership*** – Identifying potential knowledge gaps and preserving current knowledge requires gathering and maintaining a great deal of comprehensive information across the organization. Such a significant effort can only be realized with a concentrated effort that requires ownership of the issue. Because most managers are focused on their immediate staff, it

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<sup>28</sup> DeLong, David W. Lost Knowledge: Confronting the Threat of an Aging Workforce. Oxford University Press, 2004. p. 39.

is unlikely that any manager would make an effort to keep informed about information resources throughout the company. The problem with lack of ownership increases with the size of the organization.

4. ***'No Time' for knowledge sharing activities*** – Effective knowledge sharing is deliberate and takes time. Most companies do not have formal process steps that prompt people to share knowledge and learning. While much knowledge is shared informally, this transfer is generally incomplete and lacks breadth across the organization.
5. ***Capturing knowledge is not enough*** – Management must do more than facilitate discrete knowledge capturing events, they must also develop systems to maintain knowledge sharing as an inherent part of doing work. Such 'built-in' systems within most organizations do not exist.
6. ***Lack of a community of practice***—Employees often know who to go to when confronted with a problem that is new to them but may have been encountered by others. The willingness to help out and share information with peers is essential to building such communities of practice.

### **8.3.1.2.2 Impacts of Lost Knowledge**

In general, the impacts of losing inherent organizational and process knowledge are not obvious. This is primarily because the effects of this lack of knowledge are not immediate or discrete. However, missing knowledge can be damaging enough to undermine company organizational and growth strategies. In the short-term, lost knowledge can result in mistakes, quality problems and disruption in performance. Some less obvious lost knowledge impacts from a more long-term impact perspective include<sup>29</sup>:

1. ***Reduced capacity to innovate*** – this is most prevalent where past knowledge is the key to development of new products and services.
2. ***Threatened ability to pursue employee growth and development*** – loss of mentors through attrition leaves remaining employees with limited guidance and ability to grow from more experienced employees' knowledge.
3. ***Reduced efficiency undermines low-cost strategies*** – if existing employees continually find themselves on the steeper portion of the learning curve, making repeated mistakes or just not as good at the job, there are fewer opportunities to enjoy process efficiencies that come from the deep knowledge and experience that develops highly-skilled workers. Operational efficiencies and, therefore, opportunities to reduce operational costs stem from continuous improvement which can only be realized through growth in process knowledge.

*An example from Boeing: Boeing offered early retirement to 9000 senior employees after a business downturn which created a shortage of skilled production workers when business picked up. The knowledge lost when the senior employees left coupled with the inexperience of the new workers caused such chaos on the 737 and 747 assembly lines that management had to shut down this operation for over three weeks to remedy the problems. The shutdown cost them \$1.6 billion and some unquantified amount of overtime by the managers trying to sort out the mess<sup>30</sup>.*

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<sup>29</sup> DeLong, David W. pp. 26-42.

<sup>30</sup> DeLong, David W. pp. 17-18.

4. ***Loss of competitive advantage*** – especially where companies pursue low cost strategies (which is often the case for manufacturers), I have discussed how lost knowledge can increase costs through inefficiencies or increased labor costs.
5. ***Creation of unexpected vulnerability*** – when knowledge “walks out the door”, it is common to realize only after the retiree is gone that they held some crucial and specific information that allowed an operation or product to meet the demands of the customer or cost structure. In addition, if there is no formal means to announce a key resource’s upcoming retirement, existing employees may not receive sufficient notice to attempt knowledge transfer from that retiree.

### 8.3.1.3 What Can Be Done to Retain Knowledge?

Retaining knowledge is not easy. Even companies who understand the implications of lost knowledge and who are doing something about it still struggle with barriers created by their existing organizational structure. For example, Boeing established a program for cross-training their highly skilled workers. Although the program was for all employees, by design more of the participants were younger, less experienced workers. While this was excellent for building younger knowledge and skills in a typically older workforce, they were faced with a dilemma when layoffs came around – layoff senior employees or the younger workers who they just invested so much training into? The Union seniority rules determined the response – the knowledge they just invested in would likely be walking out the door.

In general, there are five (5) ways to approach retaining knowledge, through:

1. ***Standardization and documentation*** – basically, write down how it is done. This is probably the easiest, but least effective method. When is the last time you read a manual?
2. ***Education and training*** – train employees in the knowledge you want them to know. This can take the form of mentoring, on-the-job training, simulation, or formal classroom.
3. ***Engineering knowledge needs out of the process*** – remove the need for the knowledge to eliminate the need to replace it. This can be accomplished by changing a process, getting new equipment or eliminating the task altogether.
4. ***Establishing alternate sources of knowledge/skill*** – hire outside contractors and use retirees as consultants if the knowledge/skills do not exist in-house.
5. ***Building a community of practice culture*** – create a peer driven ‘go-to’ structure for informal knowledge sharing that will likely influence and prompt formal knowledge sharing practices.

Keeping these methods in mind, there are some knowledge retention strategies that companies can employ immediately and other strategies that have a more long-term horizon that must develop gradually into the organization. Some suggestions for both short- and long-term strategies follow.

#### 8.3.1.3.1 Short-term Knowledge Retention Strategies

When most companies realize the real threat of the demographic cliff, they want to know: “What can we do about this right now?” The following are some short-term suggestions:

- ***Collect comprehensive employee skills information*** – having complete information on the knowledge and skills of all employees is the key to understanding the potential knowledge loss impacts of a retiree. This exercise will create a competency map of the organization. To be successful, the extraction of this information must coincide with the type of personal information already being sought from the employee and be focused (e.g., if you ask people for too much

information, they will likely see it as too time consuming and not complete a survey). Consider whether such information is already available through established systems.

- ***Anticipate and evaluate retirees and other attrition*** – human resources (HR) should keep a close watch on those who are closest to retirement or are at the highest risk for leaving and understand the knowledge and skills of those employees. In those cases where skills gaps cannot be sufficiently covered or replaced by existing employees, HR must implement a strategy for filling these gaps either via training/mentoring of existing staff or identifying an outside resource (hire-in).
  - *Potential Retiree Scoring and Prioritization Approach* – score each retiree based on his/her likelihood to retire within a specified time horizon (generally the time it will take to replace them) and the indispensability of the employee (do they hold skills or knowledge that cannot be easily replaced). Highest scores are those to focus on first.
  - *Identify Attrition Profile* – use existing HR data to identify trends or patterns regarding age of retirees and when they plan to retire, turnover among mid-career employees, internal transfers and any rapid departure of contractors.
- ***Information Technology (IT) based solutions*** – IT itself is not a knowledge retention solution, but can facilitate other methods. This is good news for companies who already have good IT systems in-place. Some ways to use existing IT systems include:
  - *Connecting people* – less experience people can identify more experienced
  - *Accelerating learning* – support for problem solving; e-learning
  - *Capturing knowledge* – collecting and organizing critical documents or personnel information
  - *Mapping human knowledge* – collecting and having search access for employee skills information that can be matched with anticipated retirees to anticipate potential skills gaps
- ***Implement knowledge-sharing practices*** – There are several ways that knowledge can be shared. The following are potential knowledge-sharing methods. Different methods will be more appropriate than others depending on the company.
  - *Interviews/Videotaping* – will only be taken advantage of if already part of the culture
  - *Training* – training can accelerate the learning of newer employees and be leverage to balance current performance with future needs. Training is most effective when there is a pressing need for the knowledge such that there will be an opportunity for immediate application.
  - *Storytelling* – creating regular events for senior employees to describe their experiences in a story telling fashion. This is a good method way to communicate and preserve company history and culture
  - *Mentoring* – matching new employees with veterans. It is important that clear goals are set for the mentoring relationship to be effective.
  - *Knowledge Reviews* – Incorporate formal post-project reviews into the work system. These reviews will answer questions such as: What was supposed to happen? What actually happened? Explain any differences. What can we learn from this or do differently next time?

#### **8.3.1.3.2 Long-term Knowledge Retention Strategies**

Once companies are able stop the flood of lost knowledge, they must then turn to more long-term knowledge retention strategies so that keeping the right information and skills in-house becomes more

inherent in the way they do business. Long-term strategies relate more to how employees are managed both in terms of retention and prediction of leaving. The following are some of these long-term knowledge retention strategies:

- ***Improve career management practices*** – create clear expectations and paths for growth and progression so employees want to stay.
- ***Phased retirement programs*** – many retirees fear an abrupt close to their career, especially if they have been with the company for a long time. Creating phases of retirement can serve to comfort the employee with a more gradual retirement process, give more visibility to when an employee will retire, and create more systematic and clear timeframes for knowledge transfer to existing employees. Phased retirement may include reduced responsibilities, reduced work hours, flex-time or job sharing.
- ***Succession planning*** – plan for who will fill critical roles next to provide opportunities for the successor to garner the knowledge from the predecessor.
- ***Create a culture that identifies and retains valuable employees*** – show interest in employees with high skill levels and rewarding them for amassing knowledge to help retain key employees and, therefore, key company knowledge.
- ***Reinvent recruiting process*** – in addition to recruiting top candidates, perform targeted recruiting that will fill anticipated knowledge and skills gaps created by retirees or others who will be filling retirees' roles when they are gone.
- ***Incorporate appropriate knowledge-sharing practices*** – review knowledge-sharing options (as described above) and determine which practices mesh with the current company organization and structure; incorporate these practices into the standard work system.

#### **8.3.1.4 Effective Knowledge Transfer**

Knowledge transfer can be challenging both because there are different forms of knowledge and different stages of organizational memory. Knowledge is both explicit and tacit. Explicit knowledge is the easiest to manage because it can be written down and shared without need for the original resource to be present. On the other hand, tacit knowledge such as beliefs, images, intuition, mental models and expertise driven skills are not easily captured and require the original keeper of the knowledge to be present during the transfer.

In addition to the existence of different types of knowledge, there are also different stages of knowledge transfer that make up organizational memory including acquisition, storage and retrieval. Each of these stages must be facilitated by the company for knowledge transfer to be effective.

##### **8.3.1.4.1 Explicit Knowledge Transfer**

Explicit knowledge transfer is fairly straight forward – generally just a transfer of basic written or electronic data. The challenge with explicit knowledge is to make sure that there are standard methods that capture knowledge at each of the knowledge transfer stages. The most common way to for companies to capture explicit knowledge is to establish a standardized and centralized means of both electronic and hard copy documentation. This is commonly accomplished by have a filing system and shared drive electronic data storage. The important aspect here is to make sure such storage systems are structured and standardized such that everyone knows how and where to put new information, the system

is stable and protected from loss (e.g., electronic back-up) and the information storage and retrieval is intuitive and easy.

The most common difficulties with explicit knowledge is when it is complicated to access or find. This happens most commonly when individuals maintain person files that are not shared with others or when there is no standard filing system used by everyone. Combating these most common difficulties will improve explicit knowledge transfer.

#### **8.3.1.4.2 Tacit Knowledge Transfer**

Tacit knowledge transfer is most commonly done by word-of-mouth or through direct interaction and relationships that have built over time. One way many companies effectively manage tacit knowledge transfer is through mentoring or apprenticeships. Other less used approaches that can be equally effective are storytelling and knowledge reviews (discussed earlier). This type of knowledge transfer is effective provided there is a focus on knowledge capture that will affect future decision making and not just a recounting of war stories.

The discussion of tacit knowledge transfer is a good place to mention a potential caveat related to transferring tacit knowledge between different generations – baby boomers and Gen-Xers, for example. While mentor-type relationships between these two groups is a natural match, this interaction can be challenging. This relationship may hold a potential conflict based on inherent differences between members of these two groups. Baby boomers generally place emphasis on paying dues and emphasizing respect for authority while Gen-Xers have more of a competitive nature, learn by alternative formats and do not value close personal interaction as much. In addition, experiential knowledge is among the most difficult to transfer and so will be a challenge to any relationship. Finally, we know that people value knowledge differently based on their life experience and this is a high potential difference between a baby boomer and a Gen-Xer.

#### **8.3.1.5 Knowledge Recovery - After the Knowledge is Gone**

After knowledge has ‘walked out the door’ either through retirement or attrition, there are a few options to retrieving or maintaining the potential lost knowledge or skills including utilizing retirees, outsourcing lost capabilities or regenerating the lost knowledge.

##### **8.3.1.5.1 Utilize Retirees**

Many companies have found reasonable success with bringing back retirees into the workforce on a per-diem, part time or on-reserve type basis. This can be an appealing option for both the company and the retiree as it may encourage earlier retirement by potential retirees if they know they have an avenue to return in some useful capacity. To manage the value of those retirees invited to return, I would suggest making this option available to only those employees who have been with the company for over 10 years. Finally, a more ‘on-call’ or as-needed approach requires giving cell phones to key retirees that will make them easily and quickly accessible while appealing to their desire to stay connected.

##### **8.3.1.5.2 Outsource Lost Capabilities**

After a capability is lost due to a retirement or employee leaving, a company may choose to outsource that capability rather than re-developing the capability from within. This is most often the case when the capability is needed immediately and developing this internally will take too long. The caveat for outsourcing is that it will not develop the ability for the organization to learn from this capability and may make it more difficult to trouble shoot future related problems.

### **8.3.1.5.3 Regenerate Lost Knowledge**

Regenerating lost knowledge can be very difficult because it generally requires the social network of the employee who left to be reconstructed. This is a time intensive process, but could produce the most accurate and significant recreation of the lost knowledge.

## **8.3.2 Threat of the Demographic Cliff at 3WA**

Like most mature manufacturing companies, 3WA is facing the demographic cliff. Currently, the human resources (HR) department is focusing attention to this matter by taking a data driven approach to better understanding the demographic profile of their employees so that they can determine how serious of a threat the demographic cliff really is for them. 3WA's challenge is to identify clear trends in workforce demographics that will influence the organization's ability to create, produce and deliver future products or services. This includes consideration of operational, strategic, HR and knowledge management views.

### **8.3.2.1 Understanding Demographics at 3WA**

The demographics data collection is underway at 3WA and in the 'measure' stage of the 'measure-understand-control-improve' process. Their HR analytics specialist has been working to develop metrics to determine the composition and trends in behavior of the current staff at 3WA. The following is the current 3WA definition of demographics:

*"The physical characteristics of a human population, such as age, sex, marital status, family size, education, geographic location and occupation. A demographic profile is a term used to describe a demographic grouping or a market segment. A demographic profile provides enough information about the typical member of this group to create a mental picture of this hypothetical aggregate."<sup>31</sup>*

#### **8.3.2.1.1 HR Metrics and Trends**

3WA is compiling data based on salary and hourly staff, both full-time and part-time. Data such as age, gender, education, ethnicity, workforce distribution (salary, hourly, contract) and tenure (years of service) has been collected. The goal is to use such data to develop metrics to better understand the profile and trends of the organization as a whole. Characteristics of the organization built on goals, stakeholders, operations and capabilities will be captured by developing demographics based metrics to track trends in the following organizational areas:

- Culture
- Employee Services
- Business Services
- Workforce Pipeline
- People Development
- Workforce Performance
- Rewards and Recognition
- Physical Environment

Another aspect of this 'deep-dive' into the demographics data is an effort to educate and create an awareness within the HR and business community about the role of demographics evaluation in the company and the sources of the data. In addition to looking at the data internally, 3WA also plans to tap into external resources to understand and monitor regional, national and international trends to see how

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<sup>31</sup> Chidambaram, Arun. "HR Analytics: 3<sup>rd</sup> Quarter 2005". 3WA Powerpoint presentation, 2005.

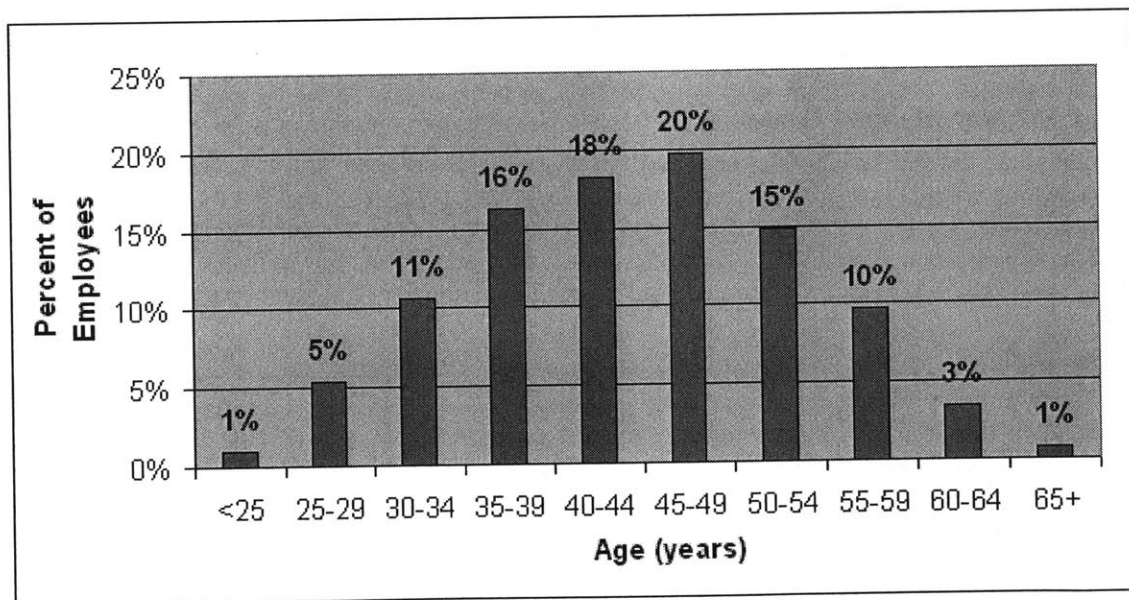
they compare. By identifying significant external trends and communicating this to management, 3WA can better understand the implications of external trends to the internal workforce pipeline capability.

3WA has set a goal to use this data and metrics to create a demographics scorecard and analyze trends on a quarterly basis. These data can then be used to forecast the demographic impact to 3WA over the next five to ten years. The data will also assist in building the criteria for the demographic scorecard and standardize demographic evaluation methods across the company. Once this demographics methodology and evaluation system is established, the company can begin to use the findings to assist with key business decisions and provide recommendations for key HR and business initiatives such as targeted recruiting. 3WA has set three initial objectives of their demographics study:

1. Determine the impact of the aging population on recruitment, retirement and retention of employees.
2. Develop compensation strategies based on demographic trends.
3. Understand the impact of lost tribal knowledge on productivity

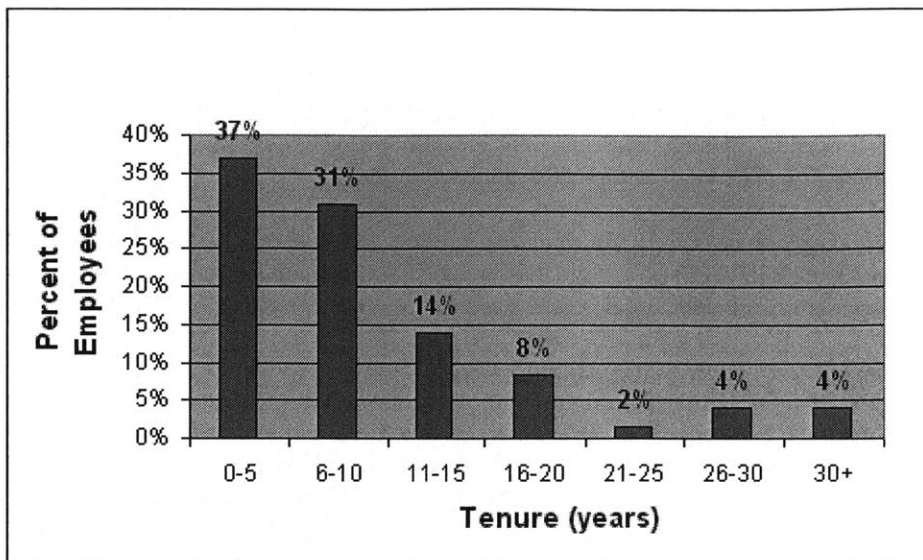
### 8.3.2.1.2 Employee Profile and Trends

Based on demographics data collected to date, 3WA has determined that the average age of employee is 44 years old with over 50% in the baby boomer age range. In addition, the average tenure (years of service) is approximately 5 years with almost 70% of employees with tenure of 10 years or less. This may be an indicator that 3WA has been hiring older workers, which would not be inline with a strategy to combat the demographic cliff. In contrast, only 17% of employees are 34 years old or younger. Figure 8-1 and Figure 8-2 below illustrate the current age group and tenure distribution of 3WA employees.



**FIGURE 8-1 – Current age distribution at 3WA (numbers have been altered for confidentiality)**





**FIGURE 8-2 – Current tenure distribution at 3WA (numbers have been altered for confidentiality)**

These findings are further supported by anecdotal observations of 3WA employees. In a discussion with a member of the skilled trades at 3WA PTO, he noted: “90% of electricians are baby boomers and this is representative of the trades in general.” He also indicated that this trend will likely continue because apprenticeships for skilled trades jobs are most often distributed based on seniority and so there is no effective pathway for younger people to get in the door. Again, this is a 3WA practice that is not in line with combating the demographic cliff.

### **8.3.2.2 What 3WA is Doing Now to Combat the Demographic Cliff and Knowledge Loss**

As described above, 3WA has taken a significant first step to combating the demographic cliff by working to understand their current demographic profile. They also have a clear plan for how they intend on using this data to develop trends and follow-on metrics that can help them to make better HR and business decisions based on the current position of staff and future needs of the company.

In addition to HR, other groups in the company are doing their part to develop strategic positions that will help with knowledge management at 3WA. For example, Union representatives at 3WA PTO have been considering implementing a new work category called a Meister. The word “meister” originally means “master” in German as in “master craftsman”. These Meisters would not only be the local experts in the plant, but they would also mentor other hourly employees in their area of expertise. The idea is that having specific local experts could open up other staff for extensive cross-training and develop a more flexible workforce.

3WA also has an employee profile system that is a step in the right direction towards development of a skills/talents database. Although it is good that they have this system infrastructure in-place, entering data into the system is not currently mandatory or well maintained. HR intends to garner more support for better population of this system as management better understand the importance of an extensive skills database.

### **8.3.2.3 What 3WA Should Do in the Future - Recommendations**

Although 3WA is clearly heading in the right direction with their preparation for the demographic cliff, I have a number of additional suggestions of what 3WA can do, based on my observations and the basic

data accumulated to date, to combat the demographic cliff and avoid mass loss of knowledge. These recommendations are listed below:

- ***Improve the depth and breadth of the skills/talents database*** – incorporate mandatory skills/talents reporting by each employee into the annual review process with a Supervisor confirmation that this has been completed and is accurate.
- ***Identify critical employees and work to actively retain them*** – Critical employees can be defined as those who have skills and knowledge that will be very difficult to replace. Once these employees are identified, additional efforts and incentives should be provided to retain them.
- ***Consider phased retirement strategies and using retirees as resources*** – As discussed previously, this may include per-diem, on-call, part-time or job sharing work for retirees. Not only would this be a way to access the knowledge of retirees as resources, but may provide a more attractive retirement transition for the employee. In addition, company employee costs would decrease and this phase could mark the beginning of a more active knowledge transfer period. Use retirees as ‘legacy coaches’ to mentor less experienced employees.
- ***Implement formal Knowledge Review into project process*** – As discussed earlier, as part of product development and all projects, incorporate a formal Knowledge Review step in order to learn from each experience.
- ***Align knowledge retention activities with what is rewarded*** – Incorporate expectations for effective knowledge sharing into the employee review process.
- ***Assign skilled-trades apprenticeships based on potential not just seniority*** – As described earlier, the limited number of skilled-trades apprenticeships are assigned largely based on seniority as required by Union rules. While changing this rule could be extremely difficult, it is in direct competition with reshaping the demographics of an area that retains a lot of knowledge in the plants. It is possible this could be done/negotiated if there was a commitment to a sufficient number of new slots.
- ***Continuous educations for hourly workers*** – continuous education appears to be available to salaried staff, but not generally to hourly workers. Although skilled-trades are often sent to training for specific tooling or systems, other hourly staff generally do not have such opportunities. To encourage retention and knowledge of all staff and improve moral and efficiency, some continuous education opportunities should be available to everyone. Currently, the most effective models for doing this are to negotiate joint training and workforce development funds and programs with a cents-per-work hour contribution and joint Union-management administration. Such programs are common in the automotive, aerospace, and increasingly in health care and hospitality industries.
- ***Have staff teach their own*** – use highly skilled workers to educate other staff on topics specific to 3WA. Not only would this be a less expensive training option and more focused than outside training, but would also foster a culture of internal knowledge sharing. As an example, Ford has done this through their “Master Workers” who serve as teachers to fellow workers, often via video tapes.<sup>32</sup>

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<sup>32</sup> DeLong, David W.

- ***Develop strategy to anticipate and fill skills gaps now*** – Identify critical employees and actively seek to fill those positions before those critical employees retire. As mentioned, such highly skilled workers will likely come at a premium down the road. Those approaching retirement can then train/mentor these new hires. A suggestion would be to partner with local technical schools such as MATC.

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## 9 Conclusions and Recommendations

Through the course of this study, I have come to many conclusions. Some conclusions merely reinforced my prevailing understanding, but in other cases I believe I was able to identify a gap between the organizational understanding of the problem and the true root cause. This is where I hope I have added the most value both in terms of my learning and the learning of the 3WA PTO organization. Herein, I will present a summary of my overall conclusions and provide some related recommendations.

### 9.1 Conclusions

*“Standardization is the foundation of continuous improvement; create high agreement and no ambiguity. Without this you will not have continuous improvement.”*

- Jamie Flinchbaugh, Lean Learning Center

As a framework for discussion of my conclusions, I will recall my project goals and address conclusions related to each:

#### 9.1.1 Understand the applicability and strategy for implementing a plant-wide Pull system

- ❖ In the climate of Just-in-Time (JIT) manufacturing, it is tempting to ‘get Lean overnight’. To some extent, this is what happened at 3WA PTO when inventory levels were squeezed too tight, too soon. Lean and JIT is a journey, not a destination and must be approached in a step-wise manner to allow for periods of continuous improvement followed by opportunities for the system to stabilize.
- ❖ Standardized processes and system stability along with accurate, knowledgeable and visible inventory management must be in-place before an extensive ‘Pull’ system will be successful.
- ❖ A system does not have to be 100% Push or 100% Pull. In fact, a hybrid of the two is often the best solution to managing a process. In order to identify where this Pull-Push interface should be, the attributes of the system such as process lead time, variety of the end product and customer delivery needs must be understood.
- ❖ Pull and Push systems are a tradeoff between speed and flexibility, respectively.
- ❖ A Pull system requires a tremendous amount of discipline and buy-in from all people involved; people must see success in the Pull system before they will trust it.

#### 9.1.2 Identify sources of schedule deviation in order to reduce or eliminate these deviations

- ❖ The main sources of schedule deviation are Cuts, Inserts and Repair, with the majority being from Cuts.
- ❖ Next to machine downtime, shortages of parts to Powertrain Assembly is one of the leading root causes of Cuts.
- ❖ All Cuts are not created equally. All powertrain units can be sorted into high runner units (a relatively small number of model combinations account for the majority of the production volume) and low running units (many model combinations accounting for a small portion of the

production volume). The discussion in Section 3.3.3 Cost of Cuts, demonstrated the potential for a low runner Cut unit to incur a much higher waiting time at sequencing due to their infrequent production and thus a larger potential cost impact than a Cut high runner unit.

- ❖ Cuts that happen today can cause more Cuts tomorrow (Cuts beget Cuts) when production builds ahead in the schedule or overproduces causing consumption of parts that component groups are not expecting.

### **9.1.3 Provide strategies and tools for better inventory management at the component level**

- ❖ There is no 'one-size fits all' for inventory management. Inventory management depends primarily on expected demand, lead time and the variability in both. Equally important when choosing an inventory strategy is developing an understanding of the true customer needs. The customer will determine important aspects of the inventory system including how they will signal demand, the frequency of their orders and how fast they *really* need the product.
- ❖ Inventory in itself is not a bad thing, even when striving for JIT. Inventory allows a system with inherent variability to remain consistently responsive to customer demand.
- ❖ Right-sized supermarkets can be used to provide visual production cues to mimic a Pull system.
- ❖ Better visual inventory management can greatly improve a manager's ability to understand the status of complex flow systems and make more informed production decisions.

### **9.1.4 Understand current production incentive structure to identify any alignment inconsistencies**

- ❖ Currently, production goals seem to encourage overproduction or building too far ahead in the schedule which can have negative impacts, from an inventory management perspective, on component groups.
- ❖ Measurement of cost per unit based on volume will further induce the tendency to overproduce, especially in a 'hero' culture.
- ❖ Although a schedule quality metric (minimum schedule deviations) currently exists, it is always trumped by the production numbers metric.

### **9.1.5 Identify challenges and strategies for 'pulling change' in a very traditional, tribal knowledge based culture**

- ❖ 'Change Champions' are not generally effective because they are almost always pushing change. When this champion leaves, the system will usually change back to the way it was unless the group itself owns the change.
- ❖ True 'pulling' of change happens when early successes from the change have been clearly demonstrated and people have been properly prepared to replicate this success.
- ❖ Legacy management methods by successful managers can often hide the problems in a systems.

### 9.1.6 Suggest strategies for knowledge transfer and skill retention in anticipation of the 'demographic cliff'

- ❖ Knowledge can be retained through:
  - Standardization and documentation
  - Education and training
  - Engineering knowledge needs out of the process
  - Establishing alternate sources of knowledge/skill
- ❖ There are both short-term and long-term knowledge retention strategies that should be implemented to combat the demographic cliff
- ❖ Companies fighting the demographic cliff should map organizational competencies and skills while identifying employees who own those skills and who most likely to leave the organization due to retirement or attrition. With a complete understanding of this profile, companies can begin succession planning and targeted recruiting to replace these skills, as needed.
- ❖ When considering knowledge retention strategies, it is important to recognize that knowledge comes in both explicit and implicit forms and includes human, social, cultural and structured knowledge.

## 9.2 Recommendations

In addition to recommendations suggested throughout the text, the following are a summary of my recommendations for 3WA both PTO and company-wide based on my observations and conclusions:

- ❖ Develop more standardized inventory management methods and find stability in that system before attempting full implementation of 'Pull-to-Assembly'.
- ❖ Evaluate each process to determine whether a Pull or Push system is more appropriate and if establishing if a hybrid of the two is most well suited (establish a Pull-Push interface).
- ❖ To determine appropriate inventory management for each component, evaluate the attributes of the production process and then determine the methods that complement the process.
- ❖ Design the inventory management system as a set of tools workers can use to make informed production decisions based on dynamic demand. Consider using the 'Right-Size Supermarket Calculator' to determine a good 'starting point' for parts inventory volumes that will cover the type of demand at 3WA PTO.
- ❖ Consider inventory management and supply chain strategies as part of the formal product development process.
- ❖ Develop a culture of internal suppliers and customers to aid communication between each step in the component production process.
- ❖ Develop a schedule quality metric that discourages or prohibits building too far ahead in the planned sequenced schedule or overproduction. Building ahead or overproduction in Assembly can cause a bullwhip effect back through component production, especially for those with long lead time processes.

- ❖ Develop a system that brings more visibility to high runner and low runner units. This system can be used to prioritize quick return of low running units to the schedule that fall out due to Cuts or Repair.
- ❖ For future roll-out of plant-wide initiatives, go for the sure success first
- ❖ Become more data driven to eliminate wasteful manual manipulation, reveal hidden trends and interdependencies, improve effective knowledge sharing and elevate metrics to support better discipline and accountability.
- ❖ Stop counting parts! Visual Supermarkets can show immediately if inventory levels are 'Ok' or 'Not Ok'. Emphasize inventory status rather than counting parts to build trust in new inventory management systems.
- ❖ Identify the 'Banes' and the 'Boons' and leverage the Boons to create organizational changes that will grow the company from a tribal knowledge to a process knowledge based culture.
- ❖ Prepare for the demographic cliff by identifying where the talent and skills are in the company and then work to actively retain these people or recruit to fill any gaps.
- ❖ To facilitate knowledge retention, especially from the Boons, use retirees as resources/consultants and formalize their mentorship with the high talent and skill pool. Consider phased retirement programs where retirees can be utilized as 'legacy coaches'.
- ❖ Integrate efforts to better link the social (organizational and workforce) and technical requirements of the Pull system and related manufacturing strategies.



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