EXTERNAL KANBAN SYSTEMS IN AUTOMOTIVE ASSEMBLY

by

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

Masters of Science in Management and
Masters of Science in Mechanical Engineering

In conjunction with the Leaders for Manufacturing Program
at the Massachusetts Institute of Technology
June 2000

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ABSTRACT

For the past two decades, rising customer expectations and increased global competition have forced automotive manufacturers around the world to significantly improve the efficiency of their production operations. One critical area of improvement has been in external logistics, logistics involving shipment of materials from external suppliers to final assembly plants.

This thesis focuses on potential cost savings and procedural improvements from the implementation of kanban systems for external logistics. These are called external kanban systems. This analysis covers many facets of external kanban systems, including their benefits over traditional external logistics systems, their impact on transportation methods, their effect on inventories, and their and their anticipated effect on organizational learning in the final assembly plant.

This project was pursued to reduce the cost and improve the reliability of external logistics at Ford Motor Company's Saarlouis Assembly Plant (Ford-Saarlouis). At Ford-Saarlouis, the implementation of these external kanban systems served as a critical portion of the replenishment process, as a training tool to familiarize plant employees with kanban systems, and as a template for future external logistics improvements.

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ACKNOWLEDGEMENTS

While it is impossible to acknowledge everyone that has contributed to the success of my internship and thesis, I will briefly mention those who had the greatest impact.

First, at Ford-Saarlouis, I would particularly like to thank my direct supervisor, Brian Shardan, who provided me with invaluable time, resources, and advice concerning the internship project as well as helping considerably in our transition to life in Germany. Second, I am grateful to Peter Knorst, who sponsored my internship and provided me the opportunity to participate in this unique assignment.

I would also like to thank my thesis advisors, Stanley Gershwin and Don Rosenfield, for their advisement concerning my research both on-site at Ford-Saarlouis and during the writing of my thesis.

Finally, I would like to acknowledge my spouse Chris' role in my internship and in my studies. Throughout my two years at the Leaders for Manufacturing program, Chris' constant support and insight has not only has helped me to gain perspective from my experiences but also to have an enjoyable and memorable time doing so.

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SECTION 1: INTRODUCTION AND OVERVIEW

1.1 STATEMENT OF THE PROBLEM

The 1999 European automotive market was extremely competitive. With over 50 competitive brands producing hundreds of models for increasingly small market niches, margins were shrinking and product complexity was exploding. Competitive firms no longer had to design and build a small range of limited products, but rather had to build many different products off of a few common platform (Automotive News '99 Market Data Book, 1999, p. 31). In these conditions, success was going to the manufacturer who could rapidly produce the most tailored, yet cost-competitive product.

For the manufacturing organizations within these firms, this had many implications. It meant that the production processes for newer vehicles were more complex, requiring a broader technical skillset and greater internal coordination. It also meant that product changes came more frequently and affected many different vehicles. Most importantly however, this increasing product complexity implied that for every manufacturing plant, more unique parts would have to be bought, manufactured, transported, and assembled for each vehicle sold.

Fortunately, manufacturers in Europe had been rapidly improving their ability to handle this increasing product complexity. While in 1990, The Machine That Changed the World (Womack, et. al., 1990) identified the quality gaps between European and Japanese assembly plants (as measured in assembly defects per car) at over 100%, by 1998 the quality gap had been reduced to just 19% (Automotive Industries, April 1999). Similarly, average productivity measured in assembly hours per vehicle for European firms has increased from 35 hours per vehicle (Womack, et. al., 1990) to 25 hours per vehicle (Harbour Report-Europe, 1999). Participating in these improvements, advances in logistics were being realized through the combination of increasingly sophisticated tools, novel experimentation in distribution, and deregulation within the European Union. Now, as product proliferation and product complexity began to rise sharply, the importance of these improved logistics were becoming more and more apparent.

This was definitely the case at the Ford-Saarlouis Assembly Plant. In 1998, Ford-Saarlouis launched an entirely new vehicle, the Ford Focus, which had both a higher parts count and a greater number of options than the prior vehicle they had assembled. In response to this, the plant implemented many innovative logistics solutions. However, nine months after the launch of the new process, there were still additional opportunities for improvement.

1.2 PROJECT SCOPE AND OBJECTIVES

In response to this increased importance of logistics to Ford-Saarlouis, this internship was focused on improving the material flow between suppliers and the assembly plant. This is referred to as *external logistics* (because the transport of parts is outside of the plant) and involves ordering, transporting, receiving, and tracking many thousands of individual parts. In addition, it requires close coordination with both the suppliers of transported parts and logistics providers, who coordinate incoming deliveries.

Management at Ford-Saarlouis set clear goals for the internship – design and implement multiple external-kanban systems for the plant. Having already implemented one successful external-kanban system three months earlier, the benefits became obvious and they wished to expand external kanban systems throughout the plant. The project was well defined and well supported by management, providing extensive exposure throughout (and outside) the plant, and contained clear-cut objectives with which success could be easily measured. Equally as important, within the charter to design and implement multiple external-kanban systems, Ford-Saarlouis' management gave complete freedom over how to achieve the internship's objectives.

1.3 PROJECT BACKGROUND

Ford-Saarlouis is one of five major automotive assembly plants Ford owned in Europe. Built in 1973, it is located in the German town of Saarlouis, situated in west central Germany just 15km from the French border. Since its construction, Ford-Saarlouis has played a central role in manufacturing some of Ford's most popular European vehicles, traditionally the Ford Escort and more recently, the Ford Focus.

Through the 1990s, both Ford Motor Company (Ford) and the Ford-Saarlouis assembly plant have continually improved operations and increased their competitiveness. One major initiative for Ford's vehicle operations was the 1994 launch of the Ford Production System (FPS). The goal of this initiative was to educate employees about and implement elements of lean manufacturing globally throughout all of Ford's assembly plants. FPS, which is based generally on successful facets of the Toyota Production System, is understood to be driving large-scale, long-term organizational changes in all corners of Ford's Automotive Operations. Though first launched over five years ago, each plant within Ford has different implementation timelines. Ford-Saarlouis started implementation of FPS in 1997.

The facet of FPS most pertinent to this internship is Synchronous Material Flow (SMF). SMF was used to encapsulate the many different aspects of a *pull* type material flow systems, including single-piece flows, optimal package quantities, and kanban replenishment systems[1]. Ford-Saarlouis had made significant progress in implementing SMF *internally* during the 1998 introduction of the Ford Focus, and had approximately 50% of all material on an internal pull system before the start of my internship. With continued rollout of internal SMF processes, Ford-Saarlouis' management projected to have internal SMF fully implemented by mid-2000 (for more information about SMF, please see Appendix B:, page 95).

[1] For an excellent description of the Ford Production System and Synchronous Material Flow, please reference Harrison Smith's Thesis, "Implementation of Lean Manufacturing Techniques to the Internal Supply Chain of an Automotive Assembly Plant", 1999. Smith interned at Ford's Cologne Niehl Assembly Operations in which the FPS and SMF were being implemented concurrently with Ford-Saarlouis.

With internal SMF under control, the next step was to turn to external improvements. Because external logistics vary significantly between each plant (due to varying distances between suppliers, significant differences in receiving practices, different external logistics providers, etc.), making changes to external logistics processes required many different solutions. For instance, to deliver bulky, customized parts (such as instrument panels) with a minimum of inventory, Ford-Saarlouis chose to build a neighboring supplier park with a direct conveyor connection. Similarly, a team of Ford engineers developed a sophisticated software solution called LPOS to optimize transportation and inventory efficiencies for suppliers located long distances from the plant.

This external-kanban internship project was a part of these *external* SMF improvements. Specifically, it was focused on converting local (within 50km) suppliers from an MRP-style replenishment system into a pull-type kanban system.

1.4 SUMMARY

This goal of this project, implementing external-kanban systems, was largely driven by two factors. In the larger picture, increased competition, expanding product variety, and greater product complexity has raised the importance of external logistics in automotive assembly. Second, but equally as important, Ford-Saarlouis' management recognized the importance of Ford's Synchronous Material Flow improvements and wisely pushed to expand its implementation to outside of the plant.

The project location, the Ford-Saarlouis Assembly Plant, is an excellent example of an above average European automotive assembly plant (Harbour Report – Europe, 1999). As a Ford plant, Ford-Saarlouis leads Ford's European plants in both the speed and completeness of its corporate productivity and quality improvement programs. Similarly, located in central Europe, the plant experienced a range of external logistic challenges, such as overseas shipments, multiple regulations, and language difficulties.

In summary, this project captured the complexity, difficulties, advantages, and drawbacks of implementing external-kanban systems in automotive plants and provided and excellent environment in which to observe their benefits.

SECTION 2: WHAT ARE EXTERNAL KANBAN SYSTEMS?

> "... the Toyota production system is the production method and the kanban system is the way it is managed" (Ohno, 1988, p. 33)

2.1 INTRODUCTION TO KANBAN SYSTEMS

Much has been written about kanban systems over the past thirty years. Nearly all literature which discusses the Toyota Production System, just-in-time systems, lean manufacturing, or other manufacturing systems, touch on kanban systems. To clarify the type and purpose of the kanban systems that my internship focused on, I will first define *external kanban systems* and then describe their identifying characteristics.

It is assumed that that the reader has a fundamental knowledge of the operating aspects of kanban systems prior to reading this paper. Those who are not familiar with kanban systems may want to review Yasuhiro Monden's Toyota Production System: An Integrated Approach to Just-In-Time (Monden, 1998), which provides an excellent overview of the basic mechanics of kanban systems. In addition, Shigeo Shingo's A Study of the Toyota Production System (Shingo, 1989) and Taiichi Ohno's Toyota Production System: Beyond Large Scale Production (Ohno, 1988) provide decent overviews of the production system requirements for successful kanban systems.

Finally, while it is common knowledge that kanban systems originated in Toyota Motor Company, it is not so widely understood that kanban systems and other elements of the Toyota Production System took decades to develop, even within Japan. For this reason, Appendix A: (page 92) which outlines the history of kanban systems has been included for reference. For those with little knowledge of the development of kanban systems and the Toyota Production System, it may helpful to review this section before continuing.

2.1.1 DEFINITION OF EXTERNAL KANBAN SYSTEMS

As with all kanban systems, external kanban systems are a type of material replenishment system. The *external* in external kanban denotes that this system is replenishing material external to the manufacturing plant –

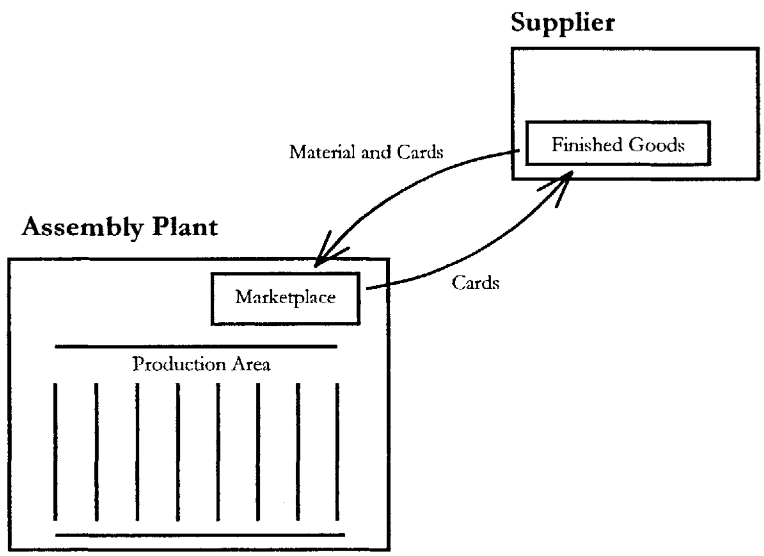

Figure 1: External Kanban System

material from external suppliers[2].

An example will help to clarify this definition of an external kanban system. This example will be used in describing the key attributes of external kanban systems that define its operation and its effectiveness. In addition, this chapter will also review the required elements of a production system necessary before implementing external kanban system.

One final note – all examples and discussion in this thesis will focus on external kanban systems operating between automotive final assembly plants and their suppliers. This is not only because my internship was in

[2] In fact, a second name for these systems is a "supplier kanban system" (Monden, 1989, p. 37.).

an automotive final assembly plant, but also because kanban systems are extensively deployed in the automotive industry.

2.1.2 EXAMPLE OF AN EXTERNAL KANBAN SYSTEM

Imagine a very elementary material reordering process for fuel caps (which you remove to refuel your car) that operates between an assembly plant, Packard Assembly, and a local supplier, Fuel-X. Both Packard Assembly and Fuel-X hold inventories of fuel caps. Packard Assembly holds its inventory in a *marketplace*[3] from which material used on the assembly line is pulled. Fuel-X keeps a fixed quantity of completed fuel caps in finished goods inventory at all times to fill orders from Packard Assembly (reference Figure 1).

Two types of fuel caps are used, gasoline caps and diesel caps. Both are delivered in cartons of 50 caps, and 600 fuel caps (12 cartons) are required per shift. Deliveries of both caps are made together three times per day, at 6:00, at 14:00, and at 22:00. Deliveries are by truck.

To replenish the material using an external kanban system, each carton of fuel caps holds a kanban card (in fact, by differentiating the gasoline and diesel cap cartons, the carton itself may serve at the kanban *card*[4]). Whenever an operator at Packard Assembly takes a carton of fuel caps from its marketplace to be used on the assembly line, she removes the card and places it in a specified mailbox. As more cartons of fuel caps are used during the shift, the mailbox fills with kanban cards.

When the next delivery arrives (at noon, for example), all of the cartons of fuel caps are delivered with kanban cards attached. While the truck is being unloaded, the truck driver walks to the mailbox and picks up

[3] Marketplace – A storage location within the assembly plant for material waiting to be delivered to the point-of-fit (where it is assembled to the vehicles). A "marketplace" exists for each part number so that parts can be found when needed and that inventory levels can be quickly visually verified.

[4] Kanban *cards* – while most kanban system use paper or plastic cards to communicate reordering information, it is sometimes easier and more reliable to substitute other items for the cards. For instance, at Ford-Saarlouis, where nearly all material is delivered in reusable packaging, the packaging itself is returned to the vendor to reorder material.

the kanban cards that represent material used during the prior shift. The truck driver then returns to Fuel-X and uses the kanban cards to assemble the next order.

This external kanban system was similar to those we implemented during this internship. The concepts behind it are simple – in fact, it is in principal one of the simplest of all kanban system. However, the challenges lie in design of the system such that it integrates into the existing Packard Assembly and Fuel-X production system, has minimal effect on the transportation efficiency for the fuel caps, and does not significantly impact the labor or system efficiencies at either site. Before we explore these challenges, let's first use this example to explore the basic elements of external kanban systems.

2.2 PRINCIPLES OF EXTERNAL KANBAN SYSTEMS

The basic principles of external kanban systems are shared with all kanban systems. However, these principles are very different from those of *traditional* external logistics systems that use forecasts to generate orders.

We can break down external kanban system into three basic principles.

1) The Reordering Process - How the downstream operation (the final assembly plant) controls incoming material and/or orders for additional material.

2) The Supply Decision– How upstream operation (the supplier) determines what, where, when, and how much to deliver.

3) In-Process Inventory Control – How inventory levels between supplier and user are controlled.

2.2.1 THE REORDERING PROCESS

In all kanban systems, the downstream operation reorders material based on recent usage. For Packard Assembly in our example (see page 16), each time a carton of fuel caps is used the kanban card is place in a mailbox signaling a material reorder. In external kanban systems, replenishment of material is based strictly on past material usage.

Replenishing material based on past usage is called a *substitution order replenishment format*[5] or more commonly, a *pull-type replenishment system*. While this system may seem obvious or intuitive, in most industries it is more common to reorder material based upon a forecast, an estimate of future demand. Ordering to a forecast not only requires more effort to generate and interpret the forecast, its natural inaccuracy also usually results in widely fluctuating inventory levels and service performance.

Principle – All kanban-systems reorder material based on past usage, not forecasts.

One exception to this rule exists. When implementing a kanban system, the initial replenishment quantity must be manually calculated based on current inventory levels, target inventory levels, and expected initial usage. At Ford-Saarlouis, where inventory levels of some items were high prior to external kanban system implementation, this often meant that delivery quantities were low (or even zero) for initial deliveries as excess inventory in the assembly plant was consumed.

2.2.2 THE SUPPLY DECISION

In kanban systems, the upstream process (the supplier, Fuel-X, for our example) determines what, when, where, and how much material to ship based solely on the kanban cards received. This information may be implicit (for example, it is obvious where Fuel-X will ship the material to, so the ship-to information need not

[5] "Substitution order format" (Shingo, 1989, p. 178) and "pull-type" are just two of many different names for this type of replenishment format. Other names include the "Later Replenishment" format (Monden, 1987, p. 43) and the "Sell one; Buy one or Ship one; Make one" format (Womack, 1996, p. 84).

be on the card) or explicit (such as the part number), but all information is clearly predetermined. Below is a sample of the type of kanban cards we used at Ford-Saarlouis.

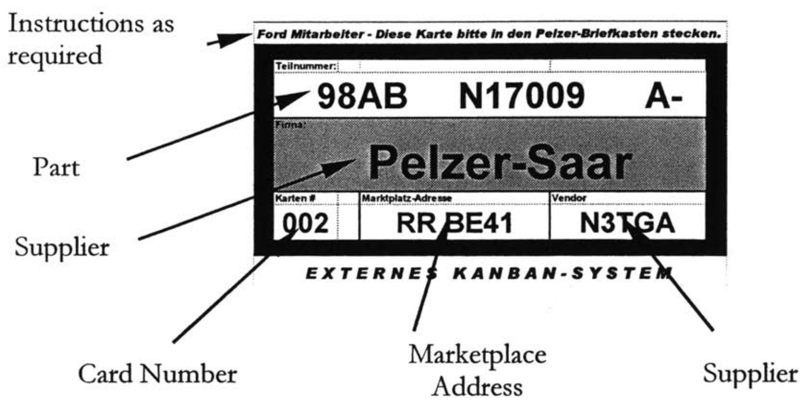

Figure 2: Sample External Kanban Card

In other external logistics systems, the supplier often has some flexibility concerning the amount of material shipped. While the desired amount of material may be set by a forecast, the actual amount produced is often dependent on batch sizes, machine availability, or packaging quantity. So, for example, if our fuel cap assembly process used a forecast-type replenishment system, the offsite forecaster may order 120 fuel caps but, because they are delivered in boxes of fifty caps, 150 caps would be delivered. This *supply flexibility*, while convenient for the upstream operation, allows for lead times increases, inventory level variation, and ambiguous communication.

Principle – External kanban system require suppliers to ship their products as ordered by the kanban *cards* they receive.

2.2.3 IN-PROCESS INVENTORY CONTROL

Kanban systems strictly control the amount of inventory in a system. In our example, each box of material in the system is labeled with a kanban card. Therefore, in-process inventory is equal to the number of circulating cards. If new cards are put into circulation, inventory rises. If cards are removed, inventory falls. Since the supplier will not ship additional material unless they have received a card, the number kanban cards strictly defines the total inventory in the system.

By adjusting the number of cards in circulation, kanban systems adjust to long term changes in production volume and mix. For instance, if sales of sunroof-equipped cars rise with warmer weather, the plant may build more sunroof-equipped cars during the summer months. When this production change occurs, plant personnel will add kanban cards to the sunroof external kanban system, which will increase internal inventories of sunroofs and allow them to meet their expected demand.

Again, this stands in stark contrast to a typical MRP or forecast type replenishment system. In forecast systems, there is no specific control over inventory levels. If the individual generating the forecast demands the supplier to ship more material, the supplier does so regardless of the amount of material currently in the system. If the forecaster's information is inaccurate (which is often the case), this can occur quite frequently.

> **Principle – The number of kanban cards in circulation strictly controls inventory levels within a kanban system.**

2.3 PREREQUISITES FOR SUCCESSFUL IMPLEMENTATION

With an understanding of the principles and distinguishing characteristics of external kanban systems, we now turn to implementation. Before installing an external kanban system, some prerequisites must be in place. In particular, these prerequisites are a level production mix, well defined delivery schedules, and disciplined card handling.

In addition, once implemented external kanban systems must follow a series of *Rules for Use*. These rules, first introduced by Taiichi Ohno in his book Toyota Production System: Beyond Large-Scale Production (1988), are well recognized as critical to any kanban system's success. A brief synopsis of these rules has been included at the end of this section.

2.3.1 LEVELED PRODUCTION

For kanban systems to act efficiently, they require relatively stable flow of material. When we explore why this is so in Section 4.3.1 (page 59), we will see that unstable delivery quantities and times force increased in-process inventory levels and drive down transportation efficiencies.

The process used to provide this constant demand for all parts is called production leveling.[6] Production leveling seeks create *a stable rate of production output and a stable take-rate for all options.*

Providing a stable rate of production is straightforward and executed by nearly all automotive assembly plants. The production output of the plant is set by the assembly line takt-time with production shortages occurring when material shortages, machine failures, or quality problems arise. With a stable rate of production, variations in market demand are accommodated in two ways. For demand exceeding plant output, the plant will run on overtime, increasing the output up to 20%. If demand falls below the plant output, the company can temporarily build inventory or stop production. Only when demand proves to be consistently above or below production, do assembly plants change the takt time of their production process and hence their target production levels.

[6] Production leveling – Other names from production leveling include "production smoothing", "load smoothing" and "Heijunka".

The second goal of production leveling, providing a stable take-rate for all options, is best understood with an example. Imagine that in aggregate, an assembly plant manufactured 20% of its cars with sunroofs. One way of achieving this production mix is to build non-sunroof-equipped cars four days per week and sunroof-equipped cars on the fifth day. This is *not* leveled production. Instead, leveled production requires that for any given time block of the day, the mix of cars is 80% non-sunroof-equipped and 20% sunroof-equipped. For instance, the production line could be sequenced to build four non-sunroof-equipped cars followed by one sunroof-equipped car.

To an assembly plant an its suppliers, the difference between leveled and non-leveled production is enormous. In the non-leveled example, the assembly plant must hold enough inventory to build a full day's worth of sunroof-equipped cars and on days when building these cars, must rearrange its production process. Similarly, suppliers will see demand spikes and only deliver sunroofs to the plant every fifth day. In contrast, using leveled production, the assembly plant needs to hold only 1/5 the amount of sunroofs (assuming daily deliveries) and sees consistent labor requirements across the week. The supplier, in turn, ships a consistent quantity of sunroofs daily and can lower finished goods inventories to well under a week's supply.

While in our example leveling production may seem quite simple, for a typical automobile containing hundreds of options (many used on fewer than 5% of vehicles sold), leveling production requires advanced computer algorithms and sophisticated scheduling systems. While all auto manufacturers operate with some form of leveled production, how comprehensive the leveling is varies.

Without leveled production, external kanban systems cannot operate efficiently. Specifically, for external kanban systems to efficiently use transportation capacity, deliveries must carry consistent quantities of parts on a daily or more frequent basis. However, this does not imply that external kanban systems are totally incapable of adjusting to the small delivery variations that occur frequently in manufacturing. In contrast, according to Toyota, a well-designed kanban system can typically handle up to ten-percent fluctuations in demand without modification (Monden, 1998, p 28).

This requirement for a leveled production is the reason why one does not see kanban systems in place at low volume, high variety manufacturing sites, such as jet engine manufacturers or specialized equipment manufacturers. If these manufacturers were to operate on a kanban material replenishment system, they would be required to hold inventory for even their most infrequently ordered parts, resulting in enormous increase of inventory levels.

2.3.2 DISCIPLINED CARD HANDLING

Since kanban cards represent units of inventory, it is critical that they not get misplaced during handling. This requires organizational discipline. This may seem obvious, but just how disciplined an operation is with kanban cards depends to a large degree on the quality of the operators, their understanding of card handling procedures, and their recognition of the importance of kanban cards.

While in any material replenishment system the handling of inventory information is important, it is especially important in kanban systems. This is because if a kanban card (which represents inventory) is lost, it can easily go unnoticed. Eventually, as more cards are lost or mishandled, enough inventories (as represented by cards) will be lost such that it starves the downstream operation, the assembly plant. Most other material replenishment systems operate with a greater amount of inventory (and thus a larger buffer before problems occur) and with secondary checks on inventory levels. This fat leaves them less prone to material shortages if inventory information is wrong or miscommunicated.

When implementing kanban systems at Ford-Saarlouis, we instilled this discipline in three ways. First, we individually trained the individuals responsible for handling the cards to insure they understood their importance. Second, we wrote critical information directly on the kanban cards. Finally, we regularly audited the process to insure no cards were being lost of mishandled. Upon finding a lost card, we attempted to find the root cause and train those individuals who had mishandled the cards. Though the launch of these systems was not without minor problems, our communication and training on disciplined card handling allowed for smoother implementation of the Ford-Saarlouis external kanban systems.

2.3.3 TIMELY REORDERING AND DELIVERIES

It is not only a problem if kanban cards are lost during handling, but it is also a problem if they are not handled in a timely matter. Often kanban-systems (both external and internal) operate with only a few hours or less of in-process inventory. For this reason, if a kanban used to reorder material is delayed or if replenishment material is late, the downstream operation can quickly run out of material.

While this again may seem obvious, in a non-kanban operation run with bloated inventories, delays in handling reordering or delivery information may be common. With the extra inventory available to cover these mistakes, this may not cause problems. However when implementing a kanban-system in this environment, this lax behavior can quickly lead to stock-outs and suspect inventory levels which can cause concern and confusion throughout the organization.

2.3.4 TRADITIONAL RULES OF KANBAN USE

In his book Toyota Production System: Beyond Large Scale Production, Taiichi Ohno introduces his "Six Rules of Use" for kanban systems (Ohno, 1988, p.30). Although other authors or practitioners have appended changes to these Rules of Use, they remain as the base elements of all kanban systems and are regularly referred to when learning about kanban systems. The Rules of Use are as follows:

1. *Downstream process picks up the number of items indicated by the kanban at the upstream process.*
   Order is placed by the downstream process, creating a pull-type replenishment format.

2. *Earlier process produces/releases items in the quantity and sequence indicated on the kanban.*

Kanban creates the order for the upstream process.

3. *No items are made or transported without a kanban.*
   This eliminates opportunity for inventory building up within the system by keeping total inventory proportional to the number of kanban cards.

4. *Always attach a kanban to the goods.*
   This keeps inventory controlled by and proportional to the number of kanban cards.

5. *Defective products are not sent on to the subsequent process. The result it 100% defect-free goods.*
   Defective products reduce the inventory in the system and cause production *flow* problems. This reduces defects, increases production stability, and allows for more rapid troubleshooting.

6. *Reducing the number of kanban cards increases their sensitivity.*
   Reducing the number of kanban cards reduces the amount of stock in the replenishment system. This allows for less time to respond to problems (such as late deliveries or defective material) before running out of material.

2.4 DISTINGUISHING CHARACTERISTICS OF EXTERNAL KANBAN SYSTEMS

Many different types of kanban systems exist – job-order kanban systems, work-in-process kanban systems, emergency kanban systems. All these different system have just a few characteristics that differentiate them from one another. We have already discussed one element of external kanban systems that makes them unique: the location where they operate, *external* to the assembly plant.

Besides their location, kanban systems can be distinguished by the action taken by the upstream process and by the ordering cycle. Because these characteristics form the foundation of some of the unique properties of external kanban systems, this paper will reference them often.

	External Kanban Systems	*Other Kanban Systems*
Location	**Internal**	External
Action	**Withdrawal**	Production Ordering
Order Point	**Constant Order Cycle**	Constant Order Quantity

Figure 3: Distinguishing Elements of Different Kanban Systems

2.4.1 WITHDRAWAL VS. PRODUCTION ORDERING KANBAN SYSTEMS

Kanban systems can be classified is by the action taken when a card is returned to the upstream operation. The two options are *withdrawal* kanban systems and *production-ordering* kanban systems (Monden, 1997, p. 27).

WITHDRAWAL KANBAN SYSTEMS

Withdrawal kanban systems are the simplest form of kanban system and are typically used when material is being replenished from an upstream warehouse or stock location. In these systems, the kanban card details the quantity that the upstream process should withdrawal and deliver to the downstream process. Our fuel cap example employs a withdrawal kanban system.

PRODUCTION-ORDERING KANBAN SYSTEMS

In production-ordering kanban systems, the kanban cards signal the upstream process to manufacture a certain quantities of material. For instance, if in our fuel cap example, cards were returned to an internal manufacturing cell that would then *mold* more fuel caps, this would be a production-ordering kanban system.

External-kanban systems are nearly always withdrawal kanban systems. These systems pull material from the suppliers finished goods inventory and deliver it to the plant's internal marketplaces. While some exceptions exist for items which are require customization based on the kanban cards received (such as automotive seats), it is generally more common for the kanban process to withdrew part from the suppliers' finished goods inventories.

2.4.2 CONSTANT-ORDER-QUANTITY VS. CONSTANT-ORDER-CYCLE

A third way of categorizing kanban system is by their reordering style (see Figure 3Figure 3). The two options of reordering style are the *constant-order-cycle* kanban system and the *constant-order-quantity* kanban system (Monden, 1997, p.25). These subsets differ by the rules that dictate when they reorder material. They are as follows:

CONSTANT-ORDER-CYCLE KANBAN SYSTEMS

Constant-order-cycle systems reorder material on a fixed time cycle. Our fuel cap example is a constant-order-cycle kanban system. Because the order times (and delivery times) are fixed, the exact quantities ordered vary.

CONSTANT-ORDER-QUANTITY KANBAN SYSTEMS

Constant-order-quantity kanban systems reorder material after a predetermined amount of material is used. If every time the assembly plant used a box of fuel caps, a new box was ordered, this would be a constant-order-quantity kanban system. In these systems reorder and delivery times fluctuate.

External kanban systems use almost exclusively constant-order-cycle systems because of the need to balance shared transportation resources, such as loading docks, receiving personnel, and trucks. To insure that these resources are not overloaded during peak service times, strict delivery schedules are required.

It is important to understand that in constant-order-cycle kanban systems, although the quantity of material ordered might change, the operator always orders in integer quantities of *cartons of fuel caps* and not individual fuel caps. Therefore, if the operator used 49 fuel caps in one order cycle (and there are 50 fuel caps per box), she would not yet reorder another box. The box must be entirely empty before she reorders. In practice, this distinction can cause confusion over the time and quantity of the reorder point.

An exception to this is for external kanban systems for long-haul deliveries (i.e. greater than 500km). In this case, costs may be driven by the truck utilization, and so ordering on a constant-order-quantity, which insures orders of full truckloads, may be more economical. Because of the complexity of these systems however, they are more the exception than the rule. For that reason, this paper will focus exclusively on constant-order-cycle systems in this paper.

PRINCIPLES

- **External kanban systems operate externally - between external suppliers and the assembly plant.**
- **External kanban systems are always withdrawal kanban systems.**
- **External kanban systems are nearly always constant-order-cycle systems.**

2.5 SUMMARY

Acting as material replenishment systems between a supplier and an assembly plant, all external kanban systems strictly follow the reorder, supply, and inventory control principles that define pull-type systems. Similarly, for successful implementation of an external kanban system, leveled production, disciplined card handling, and timely reordering and deliveries must be in place or the system will fail, causing material shortages. Finally, when analyzing external kanban system, it is important to remember their unique kanban characteristics – their external location, their withdrawal-type action on reordering, and their constant-order-cycle ordering points.

KEY POINTS

- **Kanban systems replenish material using a substitution order format (pull format) – ordering new material to replace material recently consumed.**
- **External kanban systems *cards* to control material flow between upstream and downstream processes. The *cards* may actually be empty boxes, electric signals, or any other effective means of communicating a need for replenishment.**
- **The inventory level in a kanban system is determined solely by the number of kanban cards in the system.**
- **Three critical prerequisites to any external kanban system are:**

- Leveled production.
- Disciplined card handling.
- Timely reordering and deliveries.

- External kanban systems signal a *withdrawal* action – withdrawing material from the suppliers finished goods inventories.
- External kanban systems usually use a *constant order-cycle system* - reordering material at regular time intervals but with inconsistent quantities.

SECTION 3: LOGISTICS AT FORD-SAARLOUIS

With a better understanding about the type of kanban systems implemented during my internship, we now look to the internship setting, the Ford-Saarlouis Assembly Plant. In this section we will briefly describe the general characteristics of Ford-Saarlouis before diving more deeply into the logistics systems, the gears behind material replenishment at the plant. Since the external kanban systems we implemented worked in concert with these systems, the benefits of kanban systems were largely bounded or augmented by them.

3.1 COMPANY BACKGROUND, POSITION, AND OUTLOOK

3.1.1 FORD-SAARLOUIS WITHIN FORD'S VEHICLE OPERATIONS

Ford-Saarlouis is just one of fifty-four vehicle assembly plants in Ford's Vehicle Operations Division ("Ford 1999 Worldwide Plant Guide"). These plants, as is typical of the industry, are large, employing 1,000-7,000 employees, and complex, performing many thousands of assembly operations and managing thousands of unique parts. Naturally, vehicle assembly plants are also expensive, costing over half a billion dollars to build and generating revenues between $200,000 and $600,000 per hour.

Ford-Saarlouis' statistics reveals it to be one of the larger vehicle assembly plants in the world. It employs over 6000 persons and covers 364,000 square meters (3.9 million square feet) (Schmitt, 1997). However, as the lead plant producing one of Ford's most popular products, the Ford Focus, and as Europe's highest productivity plant (Harbor Report, 1999)[7], it holds an even greater importance than its statistics reveal. Ford-

[7]The independent Habour and Associates rating agency rated Ford-Saarlouis as the most productive (measured in labor hours per vehicle) automotive assembly plant in Europe, excluding launch hours. Launch hours are additional labor hours required for up to six months after the launch of a new vehicle, usually to address unresolved process problems. Even more impressive, after this rating was released, the Ford-Saarlouis increased its output an additional 11%, from 1590 to 1770 vehicles per day, without adding additional labor.

Saarlouis acts as a model plant for all of Ford's European plants, continuously garnering visitors with an interest in the tools and techniques the plant is using to keep ahead of the competition.

3.1.2 HISTORY OF FORD-SAARLOUIS

Ford-Saarlouis' groundbreaking ceremony occurred in 1966. Located in the German state of Saarland, sixty kilometers south of Luxembourg and just ten kilometers from the French border, the plant was ideally situated to take advantage of the highly skilled labor freed by the region's faltering steel industry. This labor force, though organized by a union, has proved to be one of the plant's greatest assets, exhibiting an extraordinary level of motivation and cooperation. Of secondary importance, Ford-Saarlouis was able to capitalize on its central European location to improve material logistics, reducing shipping times and costs into the plant.

By 1968, the plant was producing its first metal chassis at the on-site body shop. Two years later, with a paint shop and final assembly line installed and operating, Ford-Saarlouis began manufacture of the first Ford Escorts, a popular mid-sized car offered primarily in Europe. The plant continued to produce Escorts until 1998. In summer 1998, the plant was retooled to produce a more refined Escort replacement, the Ford Focus.

Figure 4: 2000 Ford Focus

3.1.3 RECENT INTRODUCTION OF THE FORD FOCUS

The introduction of the Focus came with many challenges for Ford-Saarlouis. The Focus was not only a more refined vehicle than the prior Escort model, but offered more choices for the customer (Automobil Produktion, 1999, p. 31). This increased both the number of parts in the vehicle and the complexity of the assembly process. On top of this additional complexity, Ford-Saarlouis was scheduled to increase its output capacity from 290,000 to over 400,000 vehicles by the end of the first production year. Even with careful planning and novel solutions for material handling, the logistics of material replenishment would be complicated.

Ford-Saarlouis responded to this greater complexity in many ways. To reduce the number of parts handled, they consolidated individual parts into modules, such as seat assemblies, and then outsourced entire modules. To improve upon this, they built a neighboring supplier park with a conveyor capable of delivering complete modules, such as engines or dashboards, directly to the point of fit[8]. This allowed suppliers to customize their modules for each vehicle and send them to the plant in the proper sequence just minutes before they were required on the assembly line.

However, these outsourced modules represented only a small fraction of the parts in a Ford Focus. For all of the parts which remained to be received, distributed, and assembled at the plant, Ford-Saarlouis began aggressively implementing a program called Synchronous Material Flow (SMF). SMF was a new way of approaching material replenishment and made heavy use of kanban systems.

Before implementing any external kanban systems, Ford-Saarlouis had made significant progress implementing SMF internally with the plant (for details of SMF see Appendix B:, page 95). The factory was immaculate, with proper locations for everything right down to ornamental plants clearly marked. Processes were stable, each with well-defined process parameters and an associated control sheet. All operators had gone through training and understood the tools available to them. In the areas where the process was not as well organized, improvement activities were underway.

Ford-Saarlouis' progress with SMF was also revealed in their internal logistics. When I arrived, nearly 50% of all parts were distributed via one of two internal kanban systems, the call system or the card system (for more information on these see Appendix C:, page 95). Within a year, it was expected that all of the parts would be distributed via kanban systems.

However, Ford-Saarlouis had just started expanding kanban systems to its *external* logistics. Ford-Saarlouis' first external kanban implementation was completed before the start of my internship. It was an external kanban system for firewall insulation with a local vendor just 3 kilometers away. This external kanban system had been a great success, yielding large inventory reductions and streamlining the receiving process. Management now sought to move more of Ford-Saarlouis traditional logistics systems to kanban systems.

[8] Point-of-Fit (POF) - The location on the assembly line where parts are assembled onto a vehicle. In the automotive logistics chain, this is the ultimate destination for parts assembled to vehicles.

3.2 TRADITIONAL EXTERNAL LOGISTICS AT FORD-SAARLOUIS

As opposed to Ford-Saarlouis' internal logistics, in which nearly all parts share one of two replenishment processes (see Appendix C:, page 95), external logistics processes had to be tailored to each vendor's specific needs and requirements. For instance, the geographical distance between Ford-Saarlouis and its vendors varied significantly, from as close as two kilometers to across the Atlantic Ocean. Similarly, although most material was transported by trucks, different sizes and types of trucks were used depending on the packaging attributes and the transportation economics. With so much variation between deliveries from different vendors, external logistics at Ford-Saarlouis was very complex.

Ford-Saarlouis *traditional* external logistics process scheduled deliveries based on forecasted demand for the material. This process, commonly used by both automotive and non-automotive manufacturers, had three basic steps.

1) Creating and Communicating Orders – Daily demand for each part type is forecasted based upon a planned production schedule and current in-house inventories. This demand is then translated into individual orders, communicated to each vendor every morning.

2) Scheduling Deliveries – Next, deliveries from each vendor are scheduled to minimize transportation costs while adhering to the constraints of transportation suppliers and receiving personnel.

3) Receiving Deliveries – When deliveries arrive at the plant, in-plant personnel verify and correct discrepancies in the paperwork, schedule the truck for unloading, and then unload material and move it to marketplaces within the plant.

3.2.1 CREATING AND COMMUNICATING ORDERS

The first step in the *traditional* external logistics process is forecasting the plant's demand for each of many thousands of parts. To do this, Ford-Saarlouis uses a traditional, but highly customized MRP system called CMMS. The CMMS program compares the plant's projected demand (based on a central-office forecast) with on-hand inventory to generate daily orders for each part. Every morning, these orders are sent to each supplier as well as third party logistics provider, who coordinates the incoming deliveries for each vendor.

CALCULATING ORDER QUANTITIES

In principle, using a computer to generate orders for material seems straightforward. In actuality, there are significant opportunities for error. First, the system requires that inventory counts in the CMMS system be extremely accurate. If these inventory counts are incorrect, it affects the next day's orders. For instance, if parts were scrapped and inventory levels were not updated in CMMS, CMMS would show the plant had more inventory than it actually had, and the next order placed may not request enough material. To avoid problems like this, Ford-Saarlouis has a dedicated team of *cycle-checkers* whose sole job is to verify inventory levels and make corrections in CMMS each night.

Second, with forecasts and orders being generated off of an extremely complex computer program (CMMS), there is occasionally confusion over how or why specific orders were generated. For instance, during my internship when CMMS was first implemented at Ford-Saarlouis, a single variable in this computer program was mistakenly changed. Suddenly the plant was being flooded with day's worth of additional material from vendors. Although the plant is physically unable ever consume this amount of inventory, the central planning group released the computer-generated orders to vendors, causing confusion, cost overruns, and material handling problems in the plant. Because of the complexity of the computer program, it took two days to determine the source of the problem and a full week before deliveries again began to stabilize.

COMMUNICATION

A second difficulty that arose commonly in Ford-Saarlouis' *traditional* external logistics process had to do with communication and the location of individuals responsible for placing the orders. These individuals, called *disponents* at Ford-Saarlouis, were located in a central office 300 kilometers away in Cologne, Germany. While there were undoubtedly some benefits to centralization, for the Ford-Saarlouis plant this centralization meant that special considerations, such as the amount of available storage space or availability of labor to unload trucks, were not taken into account when material orders were placed.

Just one example of this is a situation occurred near the end of my internship. A local French supplier, ITT, was closing for a national holiday not celebrated in Germany and would not be able to deliver on the day of the holiday. In addition, ITT's parts, fuel lines, were bulky and required a large amount of storage space. In preparing for the holiday, Ford's disponent in Cologne allowed ITT to ship the additional fuel lines in nearly a week early, catching the plant's receiving department entirely unprepared for the additional inventory. With not enough space to store this additional inventory in normal marketplaces, the material stayed on the loading dock, causing a week of confusion and inconvenience.

Shortly after the internship was finished, Ford-Saarlouis' management was able to move the disponent groups from Cologne to the Ford-Saarlouis plant. This was expected to result in large improvements in communication and organization. However, the disponent is still one step removed from the assembly floor and so some communication inefficiencies will remain.

The Beer Game Effect

The third effect that resulted from the Ford-Saarlouis' *traditional* replenishment system was the creation of what has been nicknamed at MIT as the "Beer Distribution Game" Effect (Sterman, 1998,11-64). This effect, named after a game which simulates a simple beer supply chain, shows how forecasting errors combined with communication delays can yield exaggerated oscillations in supply chain response. James Womack and Daniel Jones describe the effect in their book, Lean Thinking, Banish Waste and Create Wealth in Your Corporation as "created demand; that is dramatic waves of orders traveling up and down the value stream".

For Ford-Saarlouis' external replenishment system, the effect is straightforward. Because traditional ordering is based on forecasts, disponents are faced with a "stock management problem" (Sterman, 1989, p. 14-7) in which they attempt to maintain inventory levels by adjusting the *rate* of incoming material. However, since the rate of outgoing material often changes due to production problems or information errors, the systems never stabilize and both inventory and order quantities oscillate.

For example, imagine that on one day a disponent boosts orders because he feels inventory levels are too low. Unfortunately the next day he cancel orders when he realizes that fewer parts than planned had been used. In response to this action, the supplier, unaware of exactly why the orders are fluctuating, may have to first boost then cut his production. Equally as important, the supplier may exaggerate orders to second–tier suppliers in an effort to protect himself against future fluctuations. This cycle then propagates down the supply chain. As order fluctuations ripple through the supply chain, they cause both Ford and suppliers to inefficiently scramble to react to them.

While the effect of this may be small for a single part ordered daily, a typical automotive assembly plant handles several thousand parts. The cumulative effect of these many small instabilities is a general uncertainty about the proper order quantities and inventory levels. This prompts plant employees and disponents to err-on-the-safe-side and keep order quantities and inventory levels high.

SUMMARY

While these problems, accurate inventory counts, communication difficulties, and the beer-game effect of fluctuating orders did not cause problems with every part every day, they caused noticeable operating inefficiencies in creating and communicating orders. Inventory levels at Ford-Saarlouis showed a large degree of fluctuation and complaints about communication were common.

3.2.2 SCHEDULING DELIVERIES

While Cologne provides the demand information to Ford-Saarlouis' vendors, Ford-Saarlouis relies on its Lead Logistics Partner (LLP)[9] to coordinate the delivery of the material. The LLP, a common name for the third-party logistics provider, builds and maintains an extensive database of truck routes, transportation equipment required, and vendor information. On a daily basis, the LLP is responsible for insuring that deliveries from material are correct and on time.

In this role, the LLP is the central hub of the external logistics at Ford-Saarlouis. In managing the truck routes, the LLP has direct contact with both Ford's vendors and transportation companies. Similarly, the LLP is in constant contact with the plant, communicating when parts are to arrive and when they should be unloaded at Ford-Saarlouis' docks. Because changes in both the plant schedules and the vendors' schedules are common, the LLP's constant communication between the plant personnel and the suppliers provides a critical link between the two.

Using an LLP to provide external logistics support works well at Ford-Saarlouis. While it was common for the LLP to be constantly shuffling deliveries in response to problems occurring in the plant or at suppliers, these problems were the result of the design of the external logistics system and occur independently of the personnel responsible for coordinating the logistics.

Further, involvement of the LLP is critical when making improvements to Ford-Saarlouis' external logistics system. Because of their central role in both maintaining and disseminating information, the personnel in

[9] Lead Logistics Partner (LLP) – (Logistik Konzept für das 21 Jahrhundert", Automobile Produktion, Januar 1999, pp. 78). A logistics firm that coordinates the delivery of material to the plant. The LLP works closely with the manufacturing plant to communicate with suppliers and transportation providers, determine and monitor delivery schedules, and implement improvement to the external logistics system.

Ford-Saarlouis' LLP were an invaluable resource, both in providing critical information and in helping me to identify potential problems when implementing kanban systems.

3.2.3 RECEIVING DELIVERIES

The final step of Ford-Saarlouis external logistics system was to receive scheduled deliveries. The process was straightforward but by no means simple.

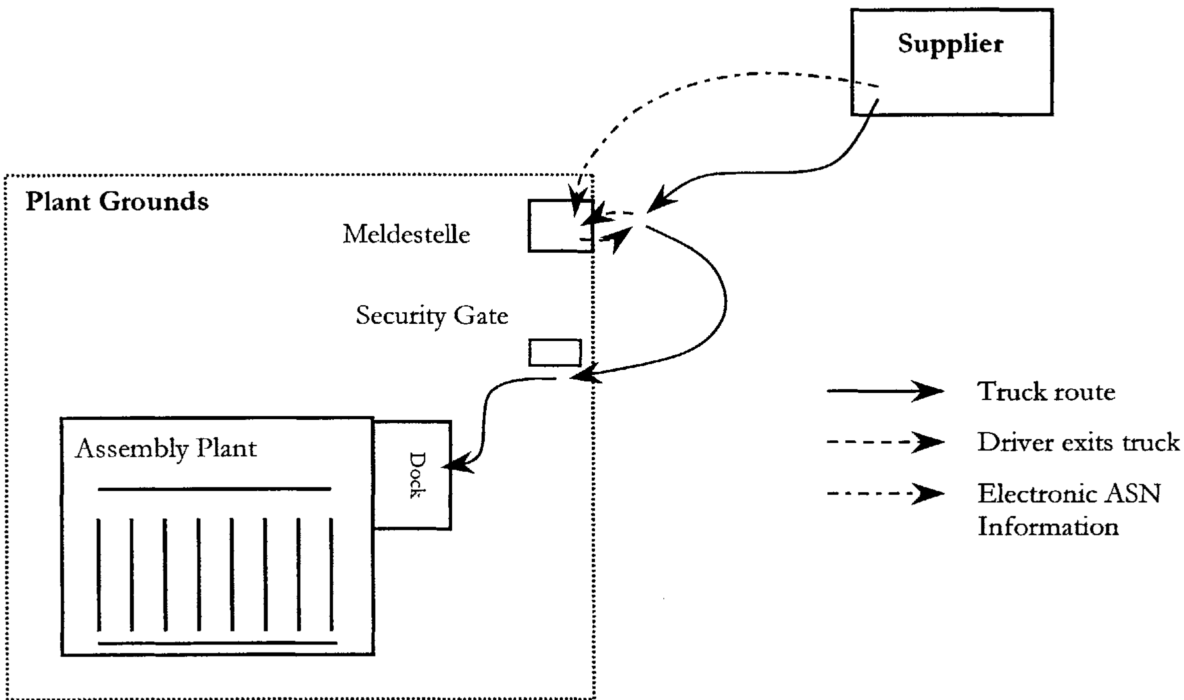

Figure 5: Delivery process for all external kanban systems (including information flow)

When a truck arrived at the Ford-Saarlouis, the driver would report to the *Meldestelle*, an external receiving gate, where he would turn in paperwork associated with his delivery. This paperwork would contain part numbers and quantities as well as other shipping and billing related information. In addition, to expedite the data entry process, vendors usually sent an electronic *Advanced Shipping Notice* (ASN) to Ford-Saarlouis before the delivery was made. When the Meldestelle clerk approved the delivery, he could transfer this ASN information directly into CMMS, Ford's MRP system, with the touch of a button. If the Meldestelle did not receive an ASN, all shipping information about the delivery would have to be entered by hand, causing a delay of an hour or more.

Once the truck was received, it was then scheduled to be *called-in* to the unloading dock. A truck was called-in only when the dock personnel were available and ready to unload the shipment. In the dock, the truck would be unloaded, the contents of the delivery checked against the shipping information, and the parts moved by forklift to their appropriate marketplace.

The vast majority of the deliveries followed a regular schedule, and hence had a predetermined *timewindow* in which they were unloaded. However, frequently a delivery was late or a special delivery had to be unloaded during a regular delivery's time window, causing the entire schedule to shift. If this happened many times in one day, the entire schedule would be rearranged, wreaking havoc for the dock supervision.

Stress on the dock supervisor and inefficient use of loading dock personnel were just a few of the negative byproducts of a disrupted time window schedule. Perhaps most important were the demurrage costs charged to Ford-Saarlouis for late unloading of trucks. Demurrage is rent for the truck and trailer charged when the truck is not unloaded in a contractually agreed upon time. For instance, if Ford-Saarlouis has a contract that requires them to unload the truck within two hours of arrival and it takes four hours before it is unloaded, the transportation company that owns the truck can charge a two-hour demurrage cost. At Ford-Saarlouis demurrage costs were significant, running in the hundreds of thousands of dollars.

3.3 GOALS OF IMPLEMENTING EXTERNAL KANBAN SYSTEMS

This internship was not an experiment or a trial balloon for external kanban systems. Rather, Ford-Saarlouis' management expected to gain immediate, tangible benefits from my work. While the ultimate objective was always to provide more reliable external logistics at a lower cost, this objective could be divided into four, more measurable goals. They are:

- Inventory reduction
- Productivity Improvements
- Plant control of external logistics
- Process leadership

3.3.1 INVENTORY REDUCTION

Because inventory levels in assembly plants are one of the most visible products of external logistics, reducing them usually gets significant attention. At Ford-Saarlouis, this was no exception. Numerous times during the internship when discussing the expected benefits of external kanban systems, a manager, supervisor, or lineworker who would expound upon the problems caused by overflowing inventory levels.

The management at Ford-Saarlouis had a particular interest in reducing internal inventory levels. With the 1998 launch of the more sophisticated Ford Focus, storage space within the plant was at a premium. This was compounded by a scheduled increase in the plant's output from approximately 1300 to 1770 vehicles per day. In addition, management had seen a large reduction of inventory levels during the pilot external kanban implementation, primarily because deliveries were increased from twice to twelve times per day. This combination of a critical space shortage and previous successes put inventory reduction high among management's goals of future external kanban implementations.

3.3.2 PRODUCTIVITY IMPROVEMENTS

A second goal of implementing external kanban systems at Ford-Saarlouis was productivity improvements. These productivity improvements were to come from a variety of sources including an expedited receiving process, a more disciplined unloading schedule, less waiting time for the truck drivers, and a simplified billing process. Because of the complex and chaotic nature of the existing external logistics, the productivity improvements were quite tangible and could generate savings that propagated to many other areas of Ford-Saarlouis.

Many of these productivity improvements resulted from a change to the billing process which external kanban systems permitted. The new billing process was called Pay-On-Production (POP), and shifted ownership of the inventory in the plant from Ford-Saarlouis to the vendor who manufactured the product. With POP, Ford paid for the product only when a finished vehicle containing the product was shipped from the assembly plant. This simple change elicited productivity improvements by eliminating paperwork at the entrance gate, the receiving dock, on the plant floor, and in the accounting department. A more detailed discussion of Pay-on-Production systems is included in the section on Eliminating Receiving with Pay-on-Production (page 51).

While a PoP system was theoretically feasible under Ford's *traditional* material replenishment system, vendors rejected the idea because of poor inventory control in the Ford plant. Under an external kanban system, inventory levels were strictly controlled by the number of circulating kanban cards and were limited to storage in strictly defined marketplaces. By paving the way to a pay-on-production system, Ford-Saarlouis management saw the opportunity for large productivity improvements.

3.3.3 PLANT CONTROL OVER EXTERNAL LOGISTICS

A third goal of implementing external kanban systems was for Ford-Saarlouis to garner additional control over its external logistics. As mentioned in Section 3.2.1 (page 34), Ford-Saarlouis did not communicate daily material orders but rather a centralized planning group located 300km away in Cologne released these orders. This caused constant headaches for the plant in the form of huge inventory fluctuations and unreliable delivery schedules.

With the additional control over external logistics that external kanban systems provided, management realized that they could make tradeoffs that were previously impossible. For instance, plant floor supervision could now control inventory levels simply by varying the number of kanban cards in circulation. Similarly, management could increase the frequency of deliveries at the expense of truck utilization, assuming that this made economic sense. With a goal of greater plant control over external logistics, Ford-Saarlouis management saw possibilities to further streamline their material flow.

3.3.4 PROCESS LEADERSHIP

The final goal of implementing external kanban systems at Ford-Saarlouis was political; Ford-Saarlouis wanted to maintain its stature as Ford's lead European plant. While this may seem of minor importance, it is critical the long term future of the plant.

Within Ford, assembly plants compete for new capital investment projects, including building new vehicles. For example, before Ford-Saarlouis was awarded the opportunity to build the Ford Focus, the plant had to complete extensive union negotiations, cost analyses and, capability studies. After this, it was compared to other plants and a final sourcing decision was made based on the facilities' overall capabilities. Those plant which lag others due to slow improvement rates and inefficient internal processes, may be passed over for replacement products and eventually closed. With Ford's European operations running below capacity, management realizes that the threat of closing an under-performing plant is real.

Secondly, the status of Ford-Saarlouis' management within Ford is largely tied to the higher management's perception of the plant. If the plant is able to show tangible examples of improvement and innovation, it reveals that management is active and aggressive. As a lead European plant, Ford-Saarlouis management had an excellent reputation that they were not about to allow to tarnish.

3.4 SUMMARY

Located in the center of Europe, Ford-Saarlouis is representative of a well-run, productive and profitable automotive assembly plant. With the bulk of its external logistics controlled by a traditional MRP system, suppliers' orders are based on forecasted demand and managed by a group of geographically dispersed individuals including disponents, LLPs, and receiving personnel. The unavoidable error of the forecasts combined with communication difficulties between parties creates inefficiencies and instabilities throughout this system.

In implementing external kanban systems, Ford-Saarlouis' management sought to minimize these negative aspects of their traditional logistics system. In doing so, Ford-Saarlouis' management used the external kanban systems to achieve four goals: reduce inventories, improve labor productivity, gain greater control over all external logistics, and to display process leadership throughout the company.

Key Points

- **Ford-Saarlouis is a better-than-average, large automotive production facility.**
- ***Traditional* external logistics at Ford-Saarlouis is driven by *forecasted* demand generated from an MRP system.**
- **Multiple personnel are involved in Ford-Saarlouis external logistics including disponents who issue daily orders to suppliers, Lead Logistics Partners who manage incoming deliveries, and receiving personnel who coordinate truck unloading and material distribution.**
- **The above individuals were dispersed, making communication difficult.**

- Ford-Saarlouis management had four goals in implementing external kanban systems:
  - Reduce inventory
  - Improve productivity
  - Gain greater control over Ford-Saarlouis external logistics.
  - Display process leadership among automotive assembly plants.

SECTION 4: EXTERNAL KANBAN SYSTEMS - WHERE ARE THE SAVINGS?

4.1 INTRODUCTION

In established manufacturing operations, costs savings and productivity increases are behind the great majority of projects. Ford-Saarlouis was no exception, and the external kanban systems we implemented each required a detailed cost analysis before commencing with the project. As it is generally understood that well designed external kanban systems can create savings, this may seem quite straightforward.

However, accurately calculating these cost savings is quite a challenge. While the direct and visible savings (i.e. transportation costs, floor space, labor hours, etc.) were generally easily calculated, much of the benefit of external kanban systems came in indirect, less quantifiable ways (i.e. reduced order variation, lower overhead support, inventory visibility, etc.). Similarly, some of the greatest benefits of external kanban systems come only after the number of implementations achieves a critical mass.

This chapter discusses both the direct and indirect cost savings attributable to external kanban systems. Since every external kanban system is unique, with differing limitations and operating parameters, this discussion will focus on the origin of the cost savings and not on absolute amounts.

4.2 LABOR SAVINGS

With thousands of employees in a typical automotive assembly plant, labor productivity is one of plant management's key measurables. In line with this, we kept a close eye on our external kanban systems' impact on employee's workload during implementation systems. What we found was external kanban systems had an indeterminate effect on labor productivity, simultaneously increasing receiving productivity and reducing distribution productivity.

4.2.1 TYPES OF LABOR AFFECTED

In manufacturing, hourly labor is broken up into direct and indirect labor.[10] Because most direct labor operators do not interact with external kanban systems, their productivity is unaffected by them. In contrast, the actions of indirect employees, such as forklift drivers, receiving clerks, and supervisory personnel[11], may be significantly affected. Therefore, this chapter will focus on the impact of external kanban systems on indirect labor.

Receiving and distribution are the two major functions of the indirect personnel who manage external logistics. Their functions are as follows (reference Figure 6 below):

1) Receiving - receive trucks, direct them to proper loading dock, and confirm receipt of material.
2) Distribution – unload trucks and move material to marketplaces.

[10] Direct labor refers to employees whose time can be directly tied to each product as it is manufactured (such as an operator installing a door on a car). Indirect labor refers to employees whose labor, despite playing a role in manufacturing, cannot be tied to any specific product (for example, a forklift driver in an assembly plant).

[11] First line supervision at Ford-Saarlouis was performed by senior hourly personnel called Meister. For this reason, I will consider first line supervision as indirect labor rather than overhead.

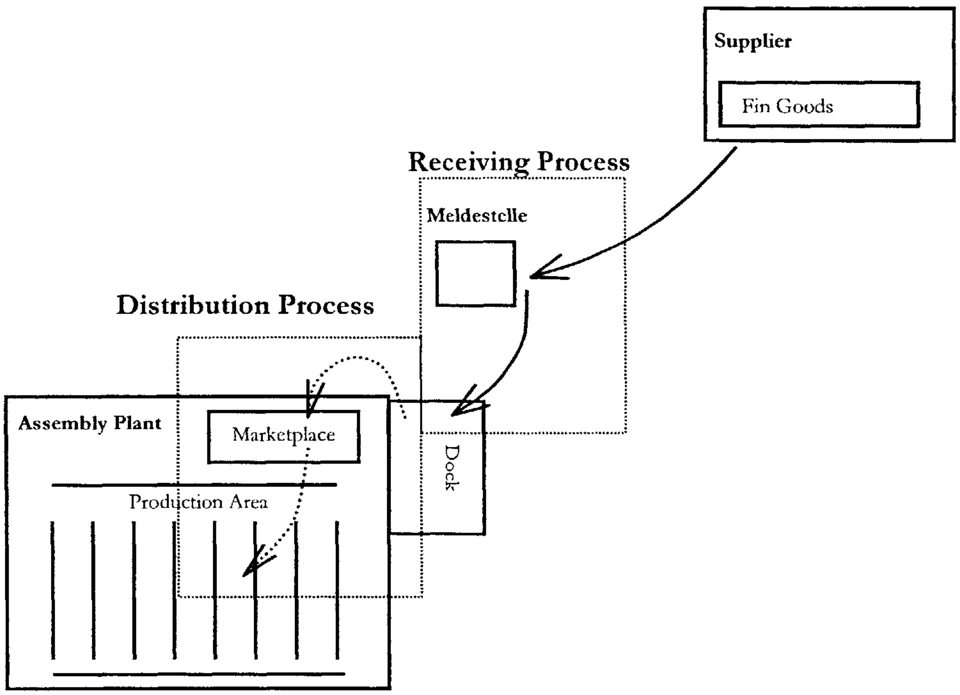

Figure 6: Diagram of the receiving and distribution processes.

4.2.2 RECEIVING LABOR PRODUCTIVITY

Of all indirect labor personnel, receiving personnel can reap the greatest rewards from implementation of an external kanban system. Receiving personnel had three primary roles: a) to receive trucks when they arrive at the plant, b) to determine when and to which loading docks trucks must continue to, and c) to confirm delivery quantities and record the transaction in a computer system.

While this may be simple in principle, it is not simple in practice. At Ford-Saarlouis, with over 140 daily truck deliveries, tight unloading schedules, and specific order-entry requirements, even small problems can disrupt schedules and force receiving personnel to scramble to reprioritize activities and reassign resources. For instance, a small paperwork error, such as a vendor neglecting to send an electronic advanced shipping notice

(ASN)[12], can delay unloading multiple trucks until receiving personnel enter all data manually into the computer. In these cases, receiving personnel are not only saddled with the unexpected and onerous tasks of re-verifying paperwork, but must also reschedule unloading times, verify unloading personnel are available, etc., all of which severely reduce their productivity.

At Ford-Saarlouis, problems like this occurred regularly. During my internship, it was rare when the standard unloading schedule was not *re-prioritized* due to late deliveries, paperwork errors, or computer problems. Similarly, it was common to see two to three trucks queued up outside a loading dock while the receiving personnel scrambled with cell phones and computer terminals to insure priority shipments were not delayed. From observation, an estimated thirty- percent or more of the typical receiving personnel's time was spent on dealing with these regular irregularities.

RECEIVING PRODUCTIVITY WITH EXTERNAL KANBAN SYSTEMS

External kanban systems can provide relief to receiving personnel in three ways. First, external kanban systems add greater discipline to the receiving process, stabilizing receiving schedules. Second, reconciliation of inventory levels, called cycle-checking, can be eliminated. And third, with a Pay-on-Production system, the transactions necessary to insure suppliers are paid are no longer necessary.

Schedule Stability

External kanban systems require discipline in their operation. Lost cards can quickly cause the assembly plant to run out of stock. Similarly, unloading delays can tie up trucks required for the next round-trip delivery.

[12] Advanced Shipping Notice (ASN) - an advanced shipping notice is an electronic document transmitted by a vendor to Ford in advance of the vendor's delivery. This document allows Ford to be prepared for receipt of the material, significantly expediting the receiving process.

Because *traditional* external logistics systems typically operate with greater buffer stocks, much less concern is placed on accurately following schedules.

With this requirement for greater logistics discipline, vendors, receiving personnel, and truck drivers all become more aware of the importance of punctual deliveries and timely unloading. While this discipline does not eliminate all delays, it reduces the constant juggling of schedules and has a positive impact on indirect labor productivity.

At Ford-Saarlouis, external kanban systems displayed this positive effect on schedule stability. The longest running external kanban system at Ford-Saarlouis (nine months old at the end of my internship) had never had a significantly delayed delivery despite a frequency of twelve deliveries per day. Similarly, it was observed that the external kanban systems installed during this internship also exhibited excellent adherence to delivery schedules just three weeks after launch. Although the exact delivery performance was not tracked before and after the external kanban system's implementation, a definite, positive impact on delivery schedule stability was observed.

Reduced Cycle Checking

Under *traditional* external logistics systems, it was absolutely critical that Ford's MRP system contained accurate inventory level data since this information was used to calculate future order requirements. To physically verify the inventory data in MRP, cycle-checking, a physical count of inventory, is done nightly. Ford-Saarlouis had over five cycle-checkers, each counting approximately 250 part numbers each night.

Under an external kanban system, future orders are determined only by returned kanban cards, totally independent of the MRP inventory data. For this reason, strict accuracy of the MRP inventory data is no longer necessary. For this reason, cycle checking of in-plant inventory levels can be eliminated for parts delivered via external kanban systems.

For any single part, these saving are quite small. However, as the use of external kanban systems spreads, so too do the savings. For instance, the external kanban systems in operation at Ford-Saarlouis currently cover approximately twenty-six part numbers, only a small portion of a cycle-checker's nightly workload. However, if implementation continues at this rate, it will free up roughly twenty percent of a cycle-checker's time by the end of next year, enough to allow him to perform other, more valuable tasks.

Eliminating Receiving with Pay-on-Production

The largest increases in receiving personnel productivity come when external kanban systems are used in conjunction with a *Pay-on-Production* payment routine (reference Section 3.3.2 , page 41). In these routines, where vendors maintain ownership of their parts until assembled vehicles containing the parts roll out of the assembly plant, Ford retains no computer tracking of internal inventory levels or of material received. Similarly, since payments to vendors are automatically generated when a vehicle leaves the plant, the number of parts received in each delivery is irrelevant, so receiving personnel no longer track it.

Under a PoP routine, supplier's inventory risks obviously increase. To offset these risks, two incentives are provided to suppliers. First, they are paid more frequently, reducing their outstanding funds in Ford's payables. Second, active participation in the PoP system is viewed very favorably among plant and purchasing employees, a fact that can be taken under consideration when negotiating addition business.

External kanban systems with a PoP boost receiving productivity enormously. In fact, deliveries of parts using this routine at Ford-Saarlouis avoided nearly all receiving activities. When drivers arrived per predetermined schedule, they drove directly through the factory's security gate to their point of unloading and were unloaded without the assistance of receiving personnel. The driver did not have to give paperwork to receiving personnel, receiving personnel did not have to enter data into computers, and cycle-checkers did not have to verify inventory levels. While strict adherence to delivery schedule and disciplined card handling were critical, the reduction in receiving labor costs was enormous.

Because a stabilization period is required between the launch of external kanban systems and the implementation of a PoP routine, the kanban systems we implemented did not incorporate PoP routines before my departure. However, Ford-Saarlouis first external kanban system did operate with a PoP routing for nearly six months without issue. In fact, in addition to eliminating paperwork for the receiving personnel, the PoP system was viewed very positively by the vendor, trucking firms, and Ford accounts payable personnel.

4.2.3 DISTRIBUTION LABOR PRODUCTIVITY

In external logistics, distribution personnel remove material from incoming trucks and transport it to its marketplace (in-plant storage location). This process could be as simple as one forklift driver moving a pallet of material from the truck to a marketplace 30 meters away. However, in a plant with over three million square feet of space, a simple distribution process like this is more often the exception than the rule.

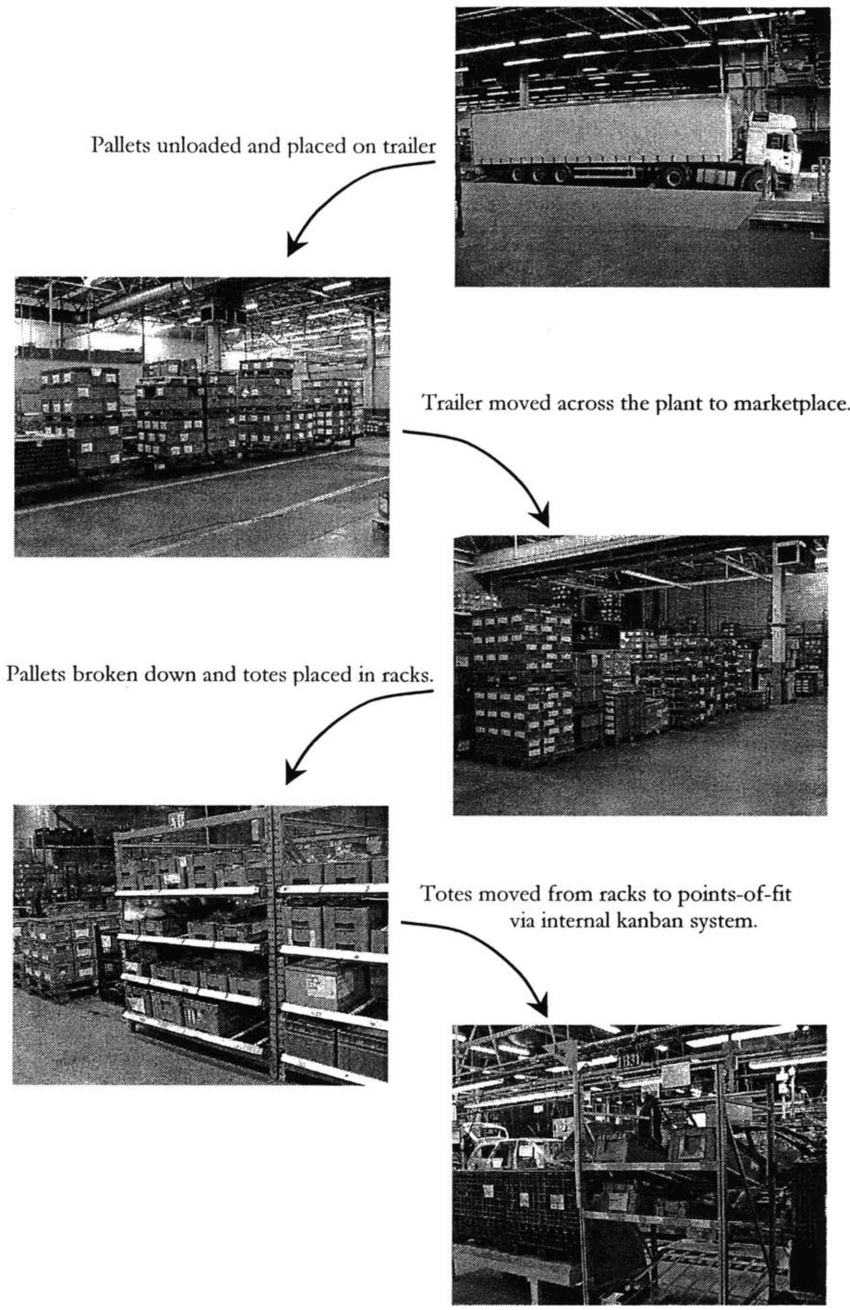

Figure 7: Internal Distribution Process

A more typical distribution process at an assembly plant is as follows. A forklift driver unloads a pallet of material and places it on a trailer. Next, a tractor driver picks up the trailer and transports it, along with other trailers, across the plant to a location nearby the part's marketplace. Here a second forklift driver unloads the pallet from the trailer and places it where it may be broken down into number of hand-portable totes. Yet another operator then sets these totes into their final marketplace - rolling racks from which the material will be removed as the assembly line requires replenishment. This distribution process can take up to 12 hours or longer to complete.

This process, as convoluted as it sounds, makes perfect sense from a labor productivity standpoint. Plant personnel handle primarily full pallets of material, allowing a single man and a forklift to move large amounts of material. Similarly, for the time consuming across-plant movements, just one tractor driver can move up to four trailers, or eight times as many pallets as a single forklift. Although this process requires coordination, slowing distribution and bloating inventories, it insures that material is moved using the most labor efficient methods.

DISTRIBUTION PRODUCTIVITY UNDER EXTERNAL KANBAN SYSTEMS

This practice of moving large amounts of material is contrary to the goal of external kanban systems, which focus on moving small amounts of material more frequently. Because of this increased distribution frequency, external kanban systems usually force an *increase* in distribution labor costs.

These increased distribution costs formed a significant hurdle for our implementation of external kanban projects at Ford-Saarlouis. In once case, we were forced to forgo a potential external kanban system when it became obvious that more frequent distribution of parts would require an additional forklift driver. Because a cost analysis revealed that the increased labor costs would more than offset any savings from the new external kanban system, no additional personnel were added.

Layout Improvements

While increased distribution labor costs are unacceptable, with some creativity one can often design an external kanban system that does not increase distribution labor requirements. One way to minimize increases distribution labor is through improvements to the plant layout, or by reducing distances between unloading locations and the marketplaces. For instance, in Ford-Saarlouis' first external kanban system, the truck unloading location was moved from roughly 300 meters from the marketplace to just twenty meters from the marketplace. With this change, Ford-Saarlouis could increase the delivery frequency from two to twelve times per day with only a small increase in distribution labor.

The importance of layout improvements is often mentioned in books on external kanban systems, but the difficulties of implementing layout improvements are not. For instance, most assembly plants have a fixed number of unloading docks, and adding new docks is an extremely expensive proposal. Similarly, while the marketplace locations are flexible, they must be located near the part's point-of-fit, which is predetermined by the vehicle's assembly process and the plant's assembly equipment. While layout improvements are often desirable, they are less often feasible.

Mixed loads

A second means of offsetting the increased distribution labor required for external kanban systems is to transport material via *mixed loads*. Mixed load deliveries will be covered in more detail when we discuss transportation costs (see discussion of mixed load deliveries on page 61), but in brief it implies distributing many small quantities of materials together, rather than large quantities one at a time. This allows the number of round trips to remain constant while inventory levels are lowered.

Mixed loads offer some potential to offer distribution cost savings, but they too are limited. First, some internal distribution, such as the trailer deliveries mentioned earlier, is already done in mixed loads. Second, like layout changes, creating efficient mixed load deliveries is difficult due to varying delivery locations and different part packaging.

Reduced Delivery Frequency

The final option for implementing external kanban system without increasing distribution labor costs, is to *not* increase the delivery frequency when implementing an external kanban system. This option will keep inventory levels high, but will allow the existing, labor-efficient distribution system to remain.

We used this method in one of our kanban system implementations with success. In this implementation, deliveries were being made from over 18km away and were being unloaded at the busiest dock in the assembly plant. When we explored the option of increasing delivery frequency, we found it not only increased transport costs, but that it also increased distribution requirements, potentially swamping the existing personnel. In the end we did not increase delivery frequency, forfeiting internal inventory reductions to keep distribution costs flat.

4.2.4 KEY POINTS

- **External kanban systems effect only receiving and distribution labor productivity**
- **External kanban systems can increase receiving labor productivity, particularly if the company and vendor adopt a Pay-on-Production routine.**
- **If external kanban systems increase delivery frequency, distribution labor productivity will fall. The impact of may be able to be minimized through layout improvements.**

4.3 TRANSPORATION SAVINGS

A second major cost component of external logistics is transportation cost. Traditionally these costs, composed primarily of fees paid to logistics (trucking) firms[13], have dominated external logistics personnel's

[13] Logistics firms – In this document, I will consider deliveries primarily by trucks for two reasons. First, all of the external kanban systems implemented at Ford-Saarlouis rely on truck deliveries. Second, with the worldwide deregulation of trucking, trucks constitute and increasing majority of the automotive industry logistics costs. The analysis however, holds true for other transportation methods.

focus for two reasons. First, they constitute the bulk of external logistics costs. Second, because transportation costs are usually determined by quotations and invoices, they are more clearly defined than internal labor or overhead costs.

In almost all cases, implementing external kanban systems *increases* transportation costs. This is the single largest reason why external kanban systems have not spread more rapidly throughout Ford and other non-Japanese manufacturers. At Ford-Saarlouis, where transportation costs were optimized (i.e. minimized) by a centralized Ford of Europe transportation department, we found increases in transport costs were met with skepticism and resistance, regardless of any offsetting savings. In fact, approval from this department was one of our greatest hurdles.

The magnitude of external kanban system's impact on transportation costs is largely dependent on the distances in which product must be transported. For instance, if a supplier is located just a few kilometers from the assembly plant, implementing an external kanban system may result in only minor increases in transport costs. Combined with the fact that transportation costs may be insignificant relative to the product's cost, the small transportation cost increase from an external kanban system may be insignificant.

In contrast, if a vendor is located far from the assembly plant, any minor changes in transportation costs could have an enormous impact. In fact, if the part is a bulky but low value item, such as a fuel tank, an external kanban system may prove to be too transportation inefficient to be of value. In these cases, it makes sense to instead focus on optimizing delivery efficiency and minimizing transportation costs. This is one reason why external kanban systems are used most often with suppliers close to the assembly plant.

To understand why external kanban systems increase transportation costs, we first break these costs into three parts:

1) Capacity Utilization – how full the truck is on average. For obvious reasons the greater the truck utilization, the lower the transportation costs.

2) Delivery Frequency – how often deliveries are made. Delivery costs rise as delivery frequency increases.

3) Off-Standard Transportation Costs – the costs of demurrage and special deliveries.

4.3.1 CAPACITY UTILIZATION

Increasing transportation equipment utilization is a primary goal of external logistics personnel. In *traditional* external logistics departments, truck utilization is maximized by adjusting outgoing orders and incoming delivery schedules to insure trucks are as full as possible. This often requires that material be delivered long before it is needed, driving internal inventories up.

EXTERNAL KANBAN SYSTEMS REDUCE TRANSPORT CAPACITY UTILIZATION

Unfortunately, because external kanban systems operate on a fixed delivery schedule[14] (and do not allow early shipment of material), they provide no opportunity to optimize equipment utilization on a daily or week-to-week basis. Instead, in external kanban systems transportation equipment must be sized to handle the peak expected demand, even if this occurs only once a year. For instance, imagine that an auto manufacturer wants to implement an external kanban system for air conditioning compressors. Normally only 1000 compressors are used each day but occasionally the usage spikes to 1500 compressors per day. In this case, the manufacturer must size the truck to handle 1500 compressors per day, although on the majority of days the truck will be underutilized, transporting only 1000 compressors.

This is an inefficiency that we ran into at Ford-Saarlouis. Under *traditional* logistics, a local fuel line supplier, sent two well-utilized trucks to Ford-Saarlouis each day. When implementing an external kanban system

[14] Most external kanban systems are constant –order-cycle system as outlined in Yasuhiro Monden's book, Toyota Production System: An Integrated Approach to Just-In-Time (1997). See Section 2.4.2 , page 27 for more details.

however, occasional spikes in demand forced us to add a third delivery. Although other labor and inventory savings easily supported the expense of this third delivery, it elicited a strong negative response from my colleagues in the transportation group.

THE IMPORTANCE OF LEVELED PRODUCTION

The solution to poor capacity utilization under external kanban systems is to implement production leveling. Leveled production stabilizes the demand by replacing batch builds with consistent daily or hourly build rates. As described by Taiichi Ohno in his book Toyota Production System: Beyond Large-Scale Production:

> "... if the later process withdraws unevenly in terms of time and quantity, the earlier process must have extra manpower and equipment (i.e. transportation capacity) to accommodate its requests." (Ohno, 1988, p. 36)

For instance, in the above example, the manufacturer would level production by building a steady 1050 air-conditioner equipped cars every day. Under this build pattern, they can lower kanban system's transportation capacity to 1050 units per day, increasing utilization and minimizing costs. However, in a plant with unpredictable market demand, material shortages, and long setup times, leveling production is easier said then done.

Production leveling is a prerequisite to implementing an external kanban system. In fact, it is critical. As Monden notes in his book Toyota Production System: An Integrated Approach to Just-In-Time:

> The smoothing of production is the most important condition for production by kanban and for minimizing idle time in regard to manpower, equipment, and work-in-progress." (Monden, 1998, p. 8)

Leveling production was a significant problem at Ford-Saarlouis. While the plant consistently produced 98% or more of the vehicles scheduled and employed very sophisticated scheduling and leveling systems, the *take-*

rate[15] for some modules was not stable. This schedule instability came from pressure to immediately boost production of the most highly demanded options without regard to the impact on the supply chain.

For instance, for the external kanban system we implemented for diesel fuel lines, past data showed that volumes would fluctuate between 400 and 600 units per day. We designed our external kanban system to handle this variation. However, shortly after implementation, demand jumped unexpectedly, nearly causing a shortage. While reviewing what had happened, we found that over the next month, the schedule for these parts was to varied from 300 to 800 units per day, over a 150% increase. While it was still economical to keep the external kanban system, this schedule instability forced us to raise inventory levels and increase transportation capacity.

To Ford-Saarlouis' credit, the plant's management was aware of the problem and was working to rectify it. While simple in principle, leveling production involved not only extremely complex computer computation and constant compensation for unexpected problems, but also requires an understanding of the importance of leveling orders from other sections of the organizations. In many ways, leveling production requires greater cross-company coordination than stabilizing production processes or implementing pull-type material replenishment system. Please see Appendix B: (page 95) for more information on Ford-Saarlouis logistics improvement efforts.

4.3.2 DELIVERY FREQUENCY

The effects of delivery frequency on transportation costs are obvious – costs rise proportionally with the delivery frequency. While this is not exactly true (some savings can come from the use of smaller trucks or through route improvements), it is an accurate rule of thumb.

[15] Take-rate – the % of vehicles that take a particular option, such as air conditioning.

It is typical to think of internal inventory reductions[16] when kanban systems are mentioned – this is often how these systems are sold within companies. But for external kanban systems, any significant inventory reduction requires an increase in delivery frequency and hence a transportation cost increase. At Ford-Saarlouis' first external kanban implementation, inventory levels dropped when deliveries were increased from two to twelve times per day, but at the expense of a large increase in transport costs. While this expense was tolerated for the initial external kanban implementation, it was not tolerated for future ones.

This leaves the implementers of external kanban systems in a predicament – how can they increase delivery frequency without increasing transportation costs? Most books on the subject only hint at solutions to this problem in, at best, a cursory manner. For instance, Shigeo Shingo in his book A Study of the Toyota Production System simply mentions that

> " ... Toyota had developed a system of frequent and continuous, mixed small lot deliveries from fabrication plants (for example, framing, painting, and machining) to the assembly line" (Shingo, 1981, p. 106)

For external kanban systems however, mixed load deliveries are a critical means for lowering inventories while simultaneously keeping transportation costs under control.

MIXED LOAD DELIVERIES

Mixed load deliveries are deliveries that transport goods between multiple suppliers and a single assembly plant. For instance, imagine a *non-mixed load* delivery pattern in which two vendors, Vendor A and Vendor B, each make one delivery to Assembly Plant Z per day (one A-Z delivery and a second B-Z delivery daily). To change to mixed load deliveries, Assembly Plant Z retains two deliveries each day, but requires the driver to pick-up product from both Vendor A and Vendor B on each delivery. This mixed load delivery schedule contains two A-B-Z deliveries.

[16] Internal inventory – internal inventory is the inventory located within an assembly plant. It does not include pipeline inventory, in

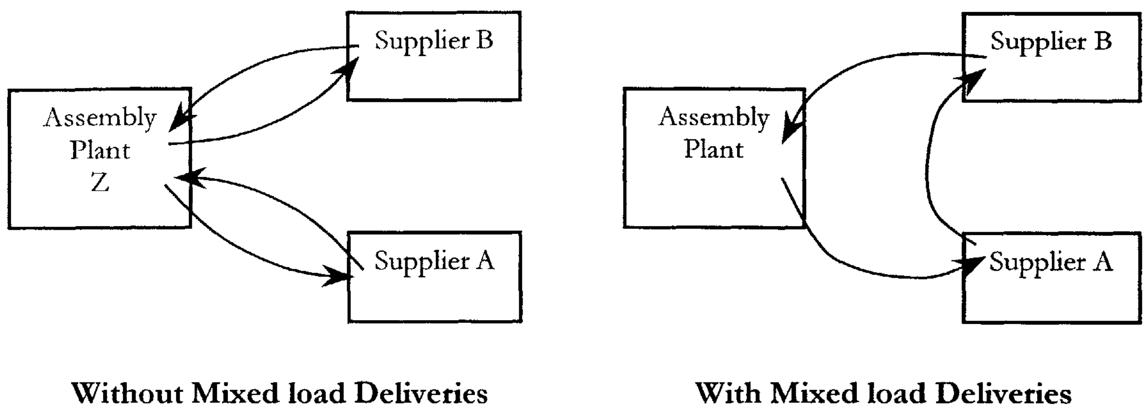

Figure 8: Non-mixed load and Mixed load deliveries.

The benefits of this mixed load delivery pattern comes from reducing internal inventory levels while holding delivery costs near their original level. In the above example, because Supplier A and Supplier B are now shipping product twice daily, inventory in Factory Z can be slashed in half. Here, transportation costs are increased only by the addition of an extra pick-up before each delivery.

Obstacles to Mixed load Deliveries

Unfortunately for external kanban systems, these additional *pick-up* costs can be prohibitive. For a mixed load delivery to be financially feasible, Vendor A and Vendor B must be proximate. At Ford-Saarlouis, and at most automobile assembly plants, this is rarely the case. With vendors serving multiple factories and multiple automobile manufacturers, their manufacturing sites are spread across Europe. Even local vendors are rarely located so close to each other that mixed load deliveries make economic sense.

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transit to the plant, or supplier's finished goods inventories.

In his book, Toyota Production System: An Integrated Approach to Just-in-Time, Yasuhiro Monden poses three potential alternatives:

> "... hiring subcontractors closer to the manufacturer, decreasing the rate of reliance on subcontractors, or withdrawing parts with a fairly large lot size."

Unfortunately these options are not particularly desirable. Often no subcontractors exist close to the assembly plant, and for most suppliers, it is not economical to move a production site just to gain transportation benefits. Similarly, attempts to in-source processes can take years of developing manufacturing competencies before the benefits are realized. More than likely, it is the third suggestion that is implemented, and instead of mixed load deliveries, single load delivery frequency is reduced to minimize transportation costs.

Similar difficulties of implementing mixed load deliveries occur during unloading and distribution of the product. Often, even if vendors are proximate enough for economical mixed load deliveries, their deliveries must be unloaded at multiple loading docks throughout an assembly plant. This adds further logistics complexity. Similarly, different vendors may require different transportation equipment or have different hours of operation. While any one of these obstacles may not be enough to make mixed load deliveries infeasible, together they can make implementation impractical.

4.3.3 NON-STANDARD TRANSPORTATION COSTS

Non-standard transportation costs refer to unplanned transportation costs. These can be divided into two types: *demurrage costs* and *priority shipping costs*. Demurrage costs are described on page 40. Priority shipping costs refer to the transport cost premiums paid for expedited material.

External kanban systems can significantly reduce non-standard transportation costs. First, by stabilizing shipping schedules into well defined, repetitive deliveries, external kanban systems, both delivery arrival times and unloading times are more consistent under external kanban systems. This reduces demurrage costs. Similarly, by using a substitution order format to stabilize orders to suppliers (as opposed to using forecasts), the plants are less likely to require priority shipping.

While it is difficult to quantify, the opportunities for cost savings are significant. Ford-Saarlouis spent well over $500,000 on annual demurrage costs and a less, but significant, amount on priority shipping. Under *traditional* logistics processes, costs of this magnitude are not unusual since orders, transportation schedules, and unloading schedules are not coordinated by the same personnel, and frequently do not go as planned.

4.3.4 KEY POINTS

- **External kanban systems increase standard transportation costs by increasing delivery frequency and lowering equipment utilization.**
- **Production leveling increases transportation capacity utilization and is critical for keeping transportation costs under control. Production leveling should be pursued prior to implementing any kanban systems.**
- **To reduce inventories while keeping transportation costs flat, implement mixed load deliveries. However, actual implementation is often not cost effective if suppliers are geographically dispersed.**
- **To lower transportation costs, lower delivery frequency. This however, increases internal inventory levels.**
- **Some standard transportation costs increases can by offset by non-standard transportation (demurrage and priority shipping) cost reductions.**

4.4 INVENTORY SAVINGS

A common misunderstanding of kanban systems is that their implementation guarantees reductions in average inventory levels. In many situations, this is untrue. Instead, when discussing a kanban system's impact on inventory levels, it is important to understand the facets of a production system which support kanban systems, such as leveled production, reduced setup times, and increased delivery frequency (see

Section 2.3, page 20). These other processes can often have a greater effect on inventory than the kanban system itself.

Kanban systems do however provide the inventory stability that make inventory reduction feasible. By stabilizing daily orders and internal inventory levels, kanban systems impact inventory by simplifying its management, clarifying internal inventory levels, and providing a system which is flexible enough to make rapid improvements.

4.4.1 EXTERNAL KANBAN SYSTEMS AND INVENTORY REDUCTION

It is common for manufacturing personnel to associate internal inventory reductions with kanban systems. For instance, at Ford-Saarlouis, when discussing external kanban systems with other employees or managers, they would often mention the benefits of plant floor inventory reduction. Undoubtedly, their focus results from the fact that, of the many factors within an assembly plant, inventory levels are one of the most visible and tangible. However, to get inventory benefits from a kanban system, one must understand the true drivers behind inventory reduction.

This preconception about kanban systems guaranteeing inventory reduction spawns from confusion over kanban systems and the original production system in which they were developed, the Toyota Production System (TPS). In general, TPS seeks to lower inventory levels. In his book, Taiichi Ohno, one of the founders of TPS, describes his philosophy on inventory as follows:

> "The greatest waste of all is inventory. If there is too much inventory for the plant to store, we must build a warehouse, hire workers to carry the goods to this warehouse, and probably buy a carrying cart for each worker." (Ohno, 1988, p. 51).

However, TPS's success in inventory reduction is not the result of its use of kanban systems, but rather stems primarily from reducing setup times and increasing delivery frequencies[17] with additional benefits resulting from leveled production. While these elements can be implemented concurrently with kanban systems, a kanban system by itself does not significantly impact average inventory levels.

It is also important to understand that in general, the space savings from inventory reductions do not create large savings. At Ford-Saarlouis, inventory space savings resulting from new external kanban systems rarely exceeded $6,000 annually, not enough to support any significant project. In fact in his research, Steven Spear outlines how even in the Toyota Production Systems, inventory levels are often increased as countermeasures against unpredictable downtime, time-consuming setups, or demand variability (Spear, 1999, p. 104).

The real savings from inventory reductions come from reduced inventory management costs. By improving the replenishment process to improve inventory stability, organization, and communication, external kanban systems eliminate the confusion that often places the greatest demands on inventory management personnel's time.

4.4.2 INVENTORY STABILITY

By placing strict bounds on the magnitude of inventory level fluctuations, kanban systems provide increased *inventory stability*. This is the result of external kanban systems' substitution order format (reference Section 2.2.1 , page 18), and the strict rule that inventory in the system can never exceed a controlled number of kanban cards (Shingo, p. 168).

To understand the cost impact of an external kanban system's inventory stability we must identify where inventory lies in external kanban systems. In external kanban systems, three types of inventory exist:

[17] Although setup time reduction plays a critical role in production kanban systems, in external kanban systems setup time is simply

Supplier Inventory – supplier's finished goods inventory ready to be shipped.

Pipeline Inventory – inventory on trucks or otherwise en route to the assembly plant.

Assembly Plant Inventory – inventory in assembly plant marketplaces.

SUPPLIER INVENTORY

Strictly speaking, suppliers' finished goods inventories are unaffected by external kanban systems. Since these finished goods inventories are outside of the external kanban loop until loaded for delivery, suppliers set their finished goods inventory levels independent of the number of external kanban cards in circulation. In fact, suppliers' who already employ *internal* kanban systems will use their internal system to regulate their finished goods inventory levels.

Despite the external kanban system's apparent independence from supplier inventory levels, suppliers often find that they are able to operate with fewer finished goods inventories when an external kanban system is implemented. This positive effect on supplier inventory levels results from two factors. First, it results from the production system prerequisites of leveled production, faster setup times, and increases in delivery frequency. Because manufacturing operations must work diligently to improve these production system attributes long before the implementation of any kanban systems, suppliers realize the benefits of less order variation and smaller, more frequent deliveries, even before a kanban system is introduced.

Secondly, suppliers can further lower their finished goods inventory levels because of the kanban system's natural tendency to smooth demand in comparison to a typical forecasted (MRP) system. Because forecasted systems place no limit on reorder quantities and encourage ordering ahead when it reduces transportation costs, spikes in order quantities force suppliers to keep large amounts of finished goods inventories (reference The Beer Game Effect, page 36). With an external kanban system, suppliers are assured order quantities

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the truck loading time. This is usually insignificant in determining the lot size that can be shipped.

never exceed the prior day's usage at the plant, thus limiting maximum order size to the assembly plant's maximum output.

While this will definitely create small, positive savings for the supplier, the cost impact of this to the automobile manufacturer is questionable. Typically for a small, difficult to quantify, savings such as this, the supplier would not share it with the automobile manufacturer nor would the manufacturer ask for a portion of it. However, as healthy, efficient, knowledgeable suppliers are key to any assembly plant's overall health, small improvements such as these are still encouraged.

PIPELINE INVENTORY

Assuming that there is no change in delivery frequency, pipeline inventory is unaffected by external kanban systems. While an external kanban system does tend to smooth order quantities (as discussed above), if the number of daily deliveries remains the same, the average pipeline inventory will also remain unchanged. For instance, in one external kanban system we implemented at Ford-Saarlouis, we chose not to increase deliveries from two to three times per day because of problems with the suppliers operating hours. In this case, we saw no significant change in pipeline inventory after implementing the external kanban system.

This however, is more the exception than the rule. Usually, when implementing a kanban system, delivery frequencies are increased to drive down upstream and downstream inventories (this is more prevalent in internal kanban systems). In fact, this is a fundamental goal of the Toyota Production System and the many production systems modeled after it. It is important to recognize that while increasing delivery frequency is desirable and will drive down pipeline inventories, it is not absolutely necessary to implement an external kanban system.

INTERNAL INVENTORY

When most assembly plant personnel refer to inventory, they are usually referring to *internal* inventory. This is the inventory that one sees when walking through an assembly plant. Since only this inventory, and no inventory outside the plant, is owned by the plant, it garners nearly all of management's focus on inventory.

As mentioned before, it is primarily the prerequisites of external kanban systems - delivery frequency, setup times, and production smoothing - that reduce the *average* amount of internal inventory. Similarly, by limiting inventory to the number of kanban cards in circulation, external kanban systems eliminate inventory peaks caused by order fluctuations. While this doesn't reduce the *average* amount of internal inventory, it does provide benefits of reducing floor space requirements, clarifying marketplace locations, and reducing safety stock levels.

Floor Space Savings

By stabilizing inventory levels, external kanban systems may allow plants to place tighter limits on the floor space allotted to each particular part. The floor space savings depend on the magnitude of inventory fluctuations (and hence the floor space requirements) before implementing external kanban systems.

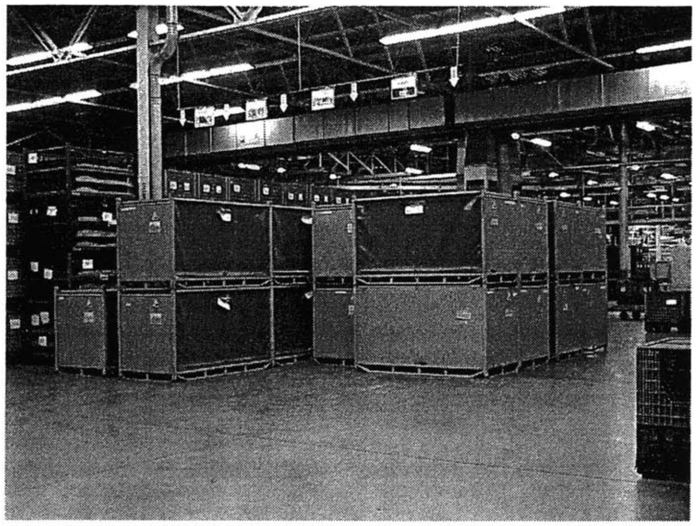


Figure 9: Refrigerator-sized racks used for fuel line delivery.

For instance, at Ford-Saarlouis, we installed external kanban system for fuel lines delivered in large refrigerator-sized racks. Before the use of an external kanban system, these containers were stored in an inventory location that was informally defined. As orders fluctuated, the inventory levels of the fuel lines would wax and wane, sometimes mixing with other stock.

With the launch of the external kanban system, we created clearly defined maximum inventory levels (note inventory location tags hanging above racks in Figure 9 above) and inventory locations. Reductions in inventory levels allowed us to save an average of 60 square meters despite a commitment lower the rack's stack height from three to two racks high (this simplified rack handling and reduced a potential safety hazard). More importantly, by clearly defining the inventory locations we clarified to all material handling personnel exactly where to place and retrieve the fuel lines.

Safety Stock

A second benefit of inventory stability is to allow a reduction in safety stock levels. Because external kanban systems by nature require an extremely reliable delivery process and well understood inventory parameters, they are typically operated with lower safety stock levels. Of course, it may take months after the initial launch before processes are deemed reliable and plant personnel are comfortable enough to reduce safety stock, but once this point is reached, reducing safety stock levels comes relatively easily.

For inventory which is not closely managed (often small parts or parts of lesser value), the reduction in safety stocks can be dramatic. At Ford-Saarlouis, one set of parts placed on an external kanban system were rolls of small, adhesive backed foam used at various places throughout the vehicle for sound abatement. Prior to implementation of an external kanban system, safety stock levels required over four weeks of inventory to be present in the assembly plant. After implementing an external kanban system, this was reduced to a single day's worth of material.

Inventory Management

The real savings from having the limited internal inventory levels that external kanban systems provide is in inventory management. These savings are difficult to quantify but include labor savings of forklift drivers required to locate stock, reductions in production problems due to not being able to find inventory, and even the instant identification of excessively low (or high) inventory levels. Considering that the ability to recognize an abnormally low inventory level could keep a critical part from shutting down a plant, the potential savings are enormous.

A perfect example of this type of inventory management savings occurred on my internship. Shortly before implementing the fuel line kanban system, two full fuel line containers (as in Figure 9) were mistakenly mixed in with empty containers because inventory locations were not clear. These full containers, which look and weigh nearly the same as empty containers, were then mistakenly shipped back to the supplier with the empties. Since inventory locations and levels were not predefined, nobody noticed their absence until the parts were required on the assembly line. The error forced six vehicles to have their fuel lines assembled in the assembly line repair area, an expensive and wasteful process.

4.4.3 KEY POINTS

- **Implementation of external kanban systems often results in inventory reductions but does not guarantee them.**
- **Much of the inventory reduction typically attributed to kanban systems result from improvements in production leveling, reduction in setup times, and increases in delivery frequency,**
- **External kanban systems provide greater inventory *stability*, which can significantly reduce floor space, safety stock and most importantly, inventory management costs.**
- **Because of fewer order fluctuations under external kanban systems, suppliers may be able to reduce their finished goods inventory.**
- **Increasing delivery frequency and leveling production provide the greatest impact on inventory reduction.**

4.5 OVERHEAD SAVINGS

While labor, transportation, and inventory costs are mildly affected by external kanban system, it is overhead reduction that provides the greatest cost savings potential. Through simplified material planning, expedited receiving, or reduced accounting, the amount of time and effort each of these processes requires can be slashed through the use of kanban systems.

4.5.1 OVERHEAD EFFICIENCY IN TRADITIONAL PRODUCTION SYSTEMS

In traditional forecasted (MRP-style) production systems, most aspects of the logistics system are scheduled and managed centrally. Planners estimate long-term material requirements. Disponents release orders to vendors on a daily basis. LLPs coordinate and adjust truck schedules daily to maximize shipping efficiency. Even receiving personnel centrally control the unloading of trucks at each gate.

FORECAST AND SCHEDULE VARIANCES

With so many different persons involved, small variations from schedules can cause large amounts of confusion and wasted time. Imagine, for instance, that a parts shortage occurs and instead of the scheduled 50% diesel engine/50% gasoline engine product mix, the factory was forced to build a 55% diesel engine/45% gasoline engine mix. Under *traditional* logistics, this could cause enormous panic. Plant personnel would have to immediately verify that enough inventories (for perhaps hundreds of different part numbers) were available to cover the change. If no, they would contact the disponent to increase orders or perhaps they would even contact the vendors directly. Similarly, LLPs would have to review, and possibly adjust, the shipping schedule to insure truck capacity is available. Receiving personnel may have to juggle the normal unloading schedule to insure the parts arrive on time. For all to go smoothly, these individuals have to communicate with each other immediately and efficiently – rarely feasible when the key individuals are remotely located and certainly distracted by other priority tasks.

In all production systems involving thousands of people and thousands of parts, reality rarely follows the schedule. In a *traditional* production system where external logistics are based on schedules and forecasts, small demand fluctuations sap the time and efficiency of overhead personnel, as described in the last chapter. However, external logistics using kanban system show a markedly more efficient response.

4.5.2 THE AUTONOMIC LOGISTICS SYSTEM

In describing kanban systems, Taiichi Ohno, one of the founders of the Toyota Production System, said it best when he described the most desirable production system as one that acts as an "autonomic nerve", responding automatically and without intervention to the normal variations in manufacturing. He describes his statement further as:

> "... an autonomic nerve means making judgements autonomously at the lowest possible level" (Ohno, p. 45)

This is exactly what external kanban systems do. Using an external kanban system, small variations in production sequence and volume[18] are automatically communicated from the assembly plant to the supplier via the kanban cards. Disponents do not need to adjust future orders. LLP personnel to not need to make delivery changes. Receiving personnel do not need to juggle truck schedules. In fact, these individuals may not even be aware of the adjustments in delivery quantity and mix, since they the autonomic response of the external kanban frees them from concern for this.

External kanban systems can go so far as to eliminate some job categories. Specifically using external kanban systems, the disponents (a daily parts planner) position may no longer be necessary[19]. As Yasuhiro Monden mentions in his discussion of kanban systems, "Planners are not needed because the pulling nature of the kanban system ... serves a indicators for when and how much material is needed." (Monden, 1997, p. 314).

Of course, these benefits do not come with the implementation of the first external kanban system. Since all overhead personnel are responsible for many parts or many vendors, it takes multiple kanban systems before the disponent or planning headcount can be lowered. For this reason, these tangible overhead benefits are usually not realized until a large portion of an assembly plant uses external kanban systems.

4.5.3 INVENTORY LEVEL AND ORDER QUANTITY VARIABILITY

A second savings in overhead costs comes from external kanban systems' ability to avoid inventory level and order quantity variability. This variability causes constant uncertainty among overhead (and non-overhead) employees over whether inventory levels and order quantities are correct. These employees then spend a

[18] "According to Toyota, demand variations of around 10% can be handled by changing only the frequency of kanban transfers without revising the total number of Kanban" (Monden, 1998, p. 28).

[19] Note: this is not to imply that long-term (monthly and greater) planning is no longer necessary. On the contrary, suppliers will need visibility into potential shifts in long-term demand to prepare their supply chain and adjust their internal inventories.

large percentage of their time checking and rechecking to confirm everything is in order, often involving many other co-workers in the process.

Section 3.2.1 (Page 36) describes how the ambiguity of forecasted orders causes constant fluctuations in order inventory levels and quantities. External kanban systems can reduce these fluctuations. First, because kanban systems limit inventory levels to the number of cards in circulation, over ordering is impossible. Second, because external kanban system reorder only based on past usage, order fluctuations cannot be more exaggerated than the usage fluctuations at the assembly plant.

In doing so, external kanban system free overhead employees from immediate concern that the reordering processes are not operating properly. As long as inventory levels are between their predefined minimum and maximum levels and order quantities approximate recent usage, the system will operate properly. Further, with control of these systems in the hands of production personnel, overhead employees can turn their attention to the long-term activities that form their primary responsibilities.

However, overhead employees must adopt one additional responsibility under external kanban systems – they must communicate any long-term changes in order levels directly to production personnel responsible for the kanban system. This communication allows the production personnel to increase or decrease the number of kanban cards in circulation, thus adjusting internal inventories to insure they are set to optimum levels. Of course, overhead employees must continue to communicate this long-term information to the suppliers, as they do under all other replenishment systems.

4.5.4 ACCOUNTS PAYABLE SAVINGS

Overhead savings also occur in the accounting department. When external kanban system are combined with Pay-on-Production (PoP) routines (as described in "Eliminating Receiving with Pay-on-Production", p. 51), not only does the workload for receiving personnel plummet, so too does the workload in the accounts payable department.

With PoP, vendors are paid for their component parts only when a vehicle containing these parts is shipped from the plant. Because all automobile manufacturers maintain databases of their completed vehicles including their installed options, the automobile manufacturer can use this information to automatically tally payment information for each vendor. Just as it is no longer necessary to enter receiving data into the computer, payment personnel no longer need to perform manual operations typically associated with the payment process.

More importantly, variances in the internal inventory to the plant do not create additional work for the accounting department. For instance, if a rack of air conditions is defective, there is no need for the vendor to be debited for the faulty parts. The vendor can simply come to the plant and replace or repair the defective part with accounting paperwork required. Similarly, no transactions are required when stock levels at the plant are adjusted. Because normally these special transactions can take a significant amount of accounts payable personnel's time, the savings from eliminating them is significant.

4.5.5 KEY POINTS

- **External kanban systems react autonomously to small changes in production levels and product mix, eliminating the need for planners (disponents) in these transactions.**
- **External kanban systems reduce inventory level and order quantity variability, lowering the frequency with which logistics personnel need to react to potential problems.**
- **External kanban systems combined with a Pay-on-Production payment routine, streamlines the accounts payable process.**

4.6 SAVINGS AT FORD SAARLOUIS

The four external kanban systems at Ford-Saarlouis (three implemented during the internship) provide an excellent backdrop to which we can review external kanban system's potential savings. Although these examples are only an initial deployment of external kanban systems, they provide a representative example of the immediate benefits of isolated external kanban systems.

4.6.1 LABOR SAVINGS

As expected, the labor savings from Ford-Saarlouis' kanban implementations were mixed. Additionally, these savings were very difficult to measure, since the labor required for receiving and distributing the material from any one kanban system represented only a small portion of a total worker's output. However, some changes could be observed.

As for receiving labor savings, it was obvious that the greatest benefits came after implementation of a Pay-on-Production system. Since only one external kanban system operated with a PoP routine (PoP was not yet implemented on the other systems), one could observe a PoP system's the relative effects on receiving tasks. While both systems saved and estimated ten minutes per delivery at the Meldestelle, only the PoP system eliminated the roughly 15 minutes required to check and verify the paperwork at the dock.

As for distribution labor savings, the results varied widely between systems. On the first kanban implementation, an increase in delivery frequency from two to twelve deliveries daily, drove distribution labor up significantly. Distribution personnel not only had to make more frequent trips to unload trucks and move parts to marketplaces, but due to a packaging change, containers could not be moved as efficiently.

For a second external kanban system distribution labor costs dropped because the kanban delivery truck used a loading dock 400 meters closer to the part's marketplace. This, combined with the fact that the parts were now delivered in individual totes rather than full pallets, eliminated a long distribution chain as shown in Figure 7. Unfortunately, because the parts constituted only a small percentage of the parts within the distribution chain, the chain could not be eliminated and these savings could not be realized.

The third and fourth external kanban system implemented had no effect on distribution labor at all. Both systems retained the original delivery frequency (to keep transportation costs low) and delivery locations, and as such, retained their original distribution process.

4.6.2 TRANSPORTATION SAVINGS

Due to an increase in delivery frequency from two to twelve deliveries daily, the first external kanban system at Ford-Saarlouis drastically increased transportation costs. While other savings offset these costs, the project sensitized Ford's transportation department to the potential transportation cost increases resulting from external kanban systems. For this reason, keeping transportation cost increases to a minimum was an explicit goal of the next three kanban systems implemented.

In two the of the next three kanban systems implemented, the transportation costs were not affected. In one kanban system, delivery frequency was kept constant and, because spare transport capacity was already available, no additional capacity was required. Although the delivery times changed, the number of deliveries did not. Similarly, in the third kanban systems, the parts being shipped represented only a small, partial-load delivery and as such, were fit into an existing kanban delivery system (the first delivery system) without any effect on transportation cost.

In the final external kanban systems, transportation costs were increased. Because additional transportation capacity was necessary to handle fluctuations in volume, an additional delivery was added. By working closely with the vendor, we were able to keep the costs increase due to this additional delivery down to 11%.

However, even this relatively small increase brought close scrutiny by Ford's transportation department before their approval of the transportation logistics.

Unfortunately, non-standard transportation costs were not tracked for the parts that were placed on external kanban system (before or after implementation). However, during the internship only a single non-standard delivery was required for all of the kanban routes, a perceived improvement over the past logistics systems.

4.6.3 INVENTORY SAVINGS

While each of the four external kanban systems at Ford-Saarlouis resulted in some inventory savings, the origin of these savings was not always the same.

In the first external kanban system implemented, inventory savings were driven by an increase in delivery frequency. With the implementation of the external kanban system, deliveries were increased from twice to twelve times daily, driving inventory levels down by over 70%. While this represented an enormous savings of floor space, these benefits were somewhat offset by increases in transportation cost.

A second external kanban system at Ford-Saarlouis achieved large inventory reductions by delivering parts in individual totes rather than in full pallet loads (one pallet = 15 totes). Because the demand for the small, foam parts delivered in this external kanban system was low, a single pallet represented several weeks worth of inventory. By delivering in single totes using an existing kanban delivery route (to keep transport costs low), this external kanban system achieved inventory reductions of over 80%.

The final two external kanban systems achieved only nominal inventory savings of approximately 20%. In these systems, delivery frequency and packaging quantity was unchanged by the implementation of the kanban system. Inventory savings from these systems resulted primarily from lower safety stocks made possible by the inventory stability which external kanban systems provide.

4.6.4 OVERHEAD SAVINGS

While overhead provides the greatest opportunity for savings from external kanban systems, the savings does not come immediately. Rather, it is only after several external kanban systems are in place, that overhead savings in the form of fewer disponents or accounts payable personnel are required. For this reason, Ford realized only marginal overhead savings from the four external kanban systems implemented. However, as Ford-Saarlouis continues implementing external kanban systems at their current rate, they will realize significant overhead savings within a few years.

4.7 SUMMARY

The savings from external kanban systems can be broken into four parts, labor savings, transportation savings, inventory savings, and overhead savings.

For labor savings, external kanban systems' produce mixed results, tending to reduce indirect labor costs by stabilizing and simplifying the receiving processes but increasing direct labor costs by increasing the frequency of distribution activity.

For transportation costs, external kanban systems typically increase standard transportation costs but can drastically reduce non-standard transportation costs. By reducing capacity utilization and increasing delivery frequency, external kanban systems increase standard transportation costs. Often this causes concern because transportation costs are an easily measured and closely tracked component of costs. But through disciplined production leveling and the introduction of clever mixed-load delivery systems it is feasible to keep these increases to a minimum.

For non-standard transportation costs, such as demurrage and special deliveries, external kanban systems can have an extremely positive effect. By stabilizing the ordering process and streamlining deliveries, external kanban systems generally reduce the amount of required non-standard transportation costs.

While external kanban system's reputation for reducing inventory levels is somewhat deserved, one should not believe that kanban systems guarantee inventory savings.. Instead, inventory savings come from two sources. First, the attributes of a production system required for a successful kanban system, leveled production, short setup times, and increased delivery frequency, can significantly reduce inventory levels. Even without the implementation of a kanban system, inventory falls under these conditions.

Second, external kanban systems themselves reduce inventory levels by stabilizing inventory levels. Stabilized inventory levels allow for floor space saving and lower safety stock levels. More importantly, stabilized inventory levels can drastically reduce inventory management costs making proper inventory locations and levels explicit and allowing potential inventory problems to be easily recognized.

Finally, external kanban systems can generate their greatest potential savings from overhead reduction. By creating a material replenishment system which reacts automatically to regular variation in the demand, eliminates forecasting error, and stabilizes delivery quantities and times, external kanban systems significantly reduce the day-to-day problems which sap a large proportion of overhead employees' time. In addition, if a pay-on-production routine is incorporated with the external kanban system, greater savings in receiving and accounts payable activities can be realized through simplified delivery and payment processes.

In summary, external kanban systems in general have a net positive effect on an assembly plant's costs. While the cost savings are often very difficult to measure, they primarily result from a kanban replenishment process that is more stable, predictable, and flexible than traditional external logistics systems.

SECTION 5: ORGANIZATIONAL LEARNING

While many of the savings mentioned in the prior four sections are difficult to quantify, rarely can any dollar figure be tied to the savings generated by organizational learning. The benefits of organizational learning accrue slowly and are hidden from sight. Nonetheless, if a company is able to capitalize on the learning that external kanban systems can promote, they stand to save far more than the other savings combined.

The reason for this is simple. While all of the other types of savings provide a static, annual benefit over existing external logistics systems, organizational learning provides continuous, compounded savings throughout the company's life. Like interest on a bank deposit, the benefits from continuous organizational learning grow exponentially.

Many theoretical frameworks have been placed around organizational learning. In Peter Senge's The Fifth Dimension: The Art & Practice of The Learning Organization he writes of "bridging teamwork into macro-creativity" and "freeing oneself of confining assumptions" (Senge, 1990). Similarly, in A New American TQM: Four Practical Revolutions in Management by Shiba, Graham, and Walden frame organizational learning as prompted by "external triggers and infrastructures" (Shiba et. al., 1993, p.541). But for understanding organizational learning in manufacturing organizations, the best framework is one introduced by Steven Spear and Kent Bowen in their Harvard Business Review article, "Decoding the DNA of the Toyota Production System" (Spear & Bowen, 1999).

In this article, Spear and Bowen identify four rules that form the engine of the Toyota Production System and power Toyota's remarkable ability to remain the most productive and efficient automotive manufacturer in the world. In generating their framework, they break all processes down into three simple categories: activities, connections, and flowpaths. They then distill these categories down to their fundamental principles, which form the foundation to organizational learning.

As kanban systems were developed with TPS, it is not surprising that they fit into this framework well. However, not all kanban systems are alike, influencing the success with which kanban systems influence organizational learning. As we continue through this analysis, keep in mind that just because a system provides great opportunity for organizational improvement, does not mean that every organization will be able to profit from it.

5.1 ACTIVITY DESIGN AND PERFORMANCE

> "Rule 1: All work should be highly specified as to content, sequence, timing, and outcome." (Spear & Bowen, p.98)

Spear and Bowen's first rule outlines the *activities* that occur in a production system. By *highly specified* they describe processes that are well defined, universally employed, and that have an obvious defect-free output. Procedures are not left up to operators' discretion and their deviations from defined procedures are readily apparent. Highly specified work promotes organizational learning by making unwanted variation visible and obvious.

As mentioned earlier in this thesis, external kanban systems by nature are highly specified. Before launching a kanban system, all inventory locations, card quantities, delivery schedules, delivery equipment, etc. must be clearly laid out and understood by all involved. At Ford-Saarlouis, we developed our external kanban systems through a series of meetings and communications between those individuals who were to have ownership of the process. This was then transferred this specific knowledge onto a process sheet that communicates the information to others.

Once developed, a well-defined kanban process will display errors in stark contrast to normal procedures. Our external kanban system did this. Just two weeks after the launch of one external kanban system, a forklift operator identified a low stock level and immediately informed his Meister (supervisor). The missing stock was quickly located nearby, and the substitute forklift driver responsible for the error was informed of the proper procedures. Under Ford-Saarlouis *traditional* external logistics system, a low inventory level would likely be considered unimportant (if noticed at all), as fluctuations in process parameters were regular and accepted occurrences. By drawing a strong distinction between normal and non-standard events, a well-designed kanban system speeds and simplifies problem detection.

Still, at Ford-Saarlouis our external kanban systems fell short of always satisfying Spear and Bowen's first rule. Spear and Bowen also articulate that even "complex and infrequent" activities must have a predefined action assigned to them (Spear & Bowen, p. 99). At Ford-Saarlouis, the process forklift drivers follow when problems occur was not well defined. Although Ford-Saarlouis' forklift drivers usually sought assistance of their Meister when problems arose, they would also contact a Kolonnenführer (group leader) or colleague. Similarly, Meister had no single, clearly defined contact for assistance, but would turn to the most available supervisor, vendor, or engineer. This flaw of an ambiguous process of getting assistance will slow Ford-Saarlouis' organizational learning.

5.2 CUSTOMER-SUPPLIER CONNECTION DESIGN

> "Rule 2: Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests or receive responses." (Spear & Bowen, p. 98)

Spear and Bowen's Rule #2 identifies how activities within a production system should *connect* with one another. In particular, these activities should connect such that communication is direct (not through a third party) and so that the expected result of the communication is clear to both parties.

Kanban systems act as the *connections* between activities. In *traditional* external logistics at Ford-Saarlouis, information travels (as orders) from the disponent to suppliers then (as product) to receiving personnel and (as inventory statistics) through the centralized computer and finally back to the disponent. It is a convoluted path at best. If a disponent notices that CMMS (Ford's MRP system) shows unusually low inventory levels one morning, it is not clear to him whether it is the result of a missed delivery, a delay in unloading, a data entry error, or any number of other potential causes. Worse yet, it is unclear who he should contact to correct the problem. Faced with this dilemma, the disponent will often choose to simply boost the day's order quantities and postpone the necessary problem solving until later.

In contrast, external kanban systems "simultaneously convey the product and information (Kanban) together" (Monden, 1998, p. 316). Thus communication is direct from the receiving personnel at the assembly plant to the supplier and vice versa. If a delivery does not arrive as scheduled, the customer (receiving personnel) contacts the supplier. If a delivery has too much material, receiving personnel contact the supplier. If material is shipped without a kanban card, receiving personnel again contact the supplier. Because the communication flow is direct, well-defined, and has an expected outcome, problems are identified and investigated immediately. In turn, individuals truly learn from their mistakes, promoting organizational learning at both sites.

5.3 PATHWAY DESIGN

> "Rule 3: The pathway for every product and service must be simple and direct" (Spear & Bowen, p. 98)

Pathways, as defined by Spear & Bowen, are systems of interconnected *activities* and *connections*. For instance, one pathway is communication path that arises when an operator finds a defective part on the assembly line. Another is the process in which changes are made to individual production operations. For logistics systems, the pathway is the route parts take as they travel through the supply chain and into newly assembled vehicles.

Like activities and connections, Spear and Bowen assert that pathways must be predetermined and unambiguous. For pathways, this implies that once an item (whether it is an order, a request for assistance, or

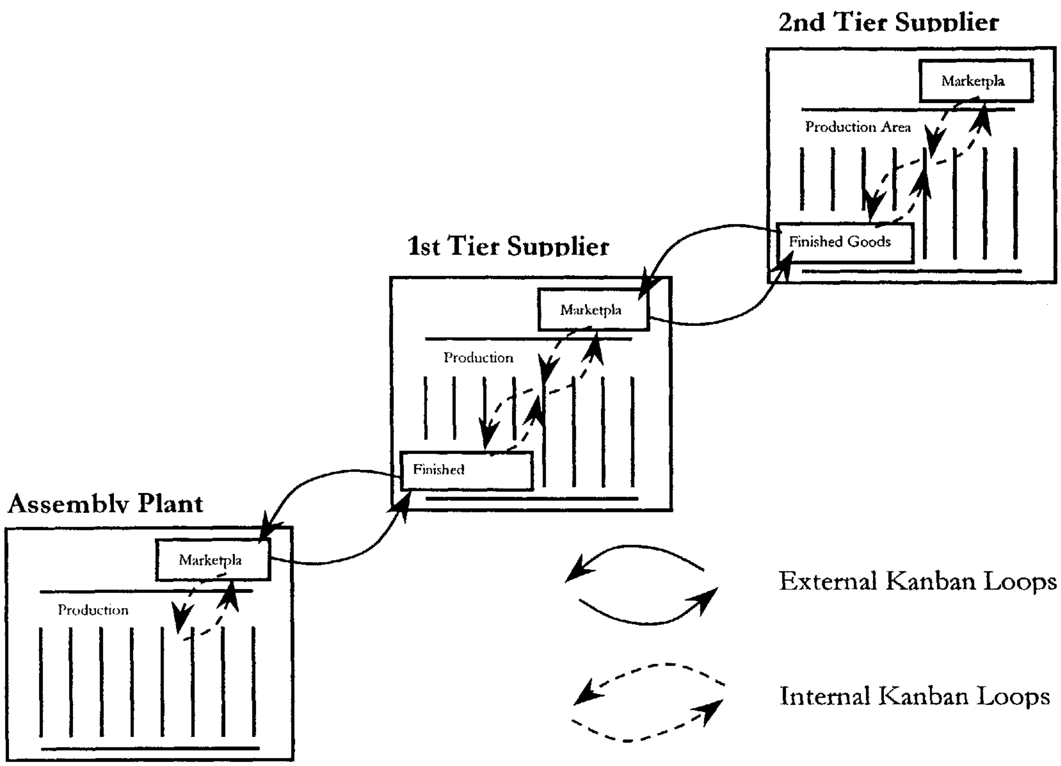


Figure 10: Multiple kanban systems form an unambiguous pathway for material flow.

a component part) starts down a pathway, it will travel down a known and predictable path without branches or diversions. For instance, in our original example of an external kanban system (see Section 2.1.2 , page 16), Fuel-X doesn't ship fuel caps to Packard Assembly unless it knows what receiving dock the truck will be received at, the marketplace where the caps will be stored, the delivery method by which the caps will be moved to their assembly line, and the process by which they will be assembled.

While a single external kanban system is an *activity*, kanban systems link to form pathways (see Figure 10). For instance, after an external kanban system delivers parts to a marketplace inside the assembly plant, an internal kanban system delivers the parts to the point-of-fit. This pathway is by nature direct and unambiguous, with only one receiving dock, one marketplace, one point of fit, and one route connecting these. If, as often is the case in other systems, product could flow to many marketplaces or deliveries to the point-of-fit could occur through a number of routes, this rule would not be satisfied.

Simple and direct pathways promote organizational learning in the way previously discussed activities and connections do – they make non-standard activities or results obvious. Employees at the lowest level of the organization can now recognize the difference between expected and faulty outcomes with ease. Most important, with the cross-linking and ambiguity of pathways removed, the root causes of these failures can be more easily tracked down and permanent solutions put into place.

5.4 IMPROVEMENT AND LEARNING

> "Rule 4: Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization." (Spear & Bowen, p. 98).

Spear and Bowen's Rule 4 outlines the fundamental elements for the process of organizational improvement under the Toyota Production System. While the three prior rules outlining *activities*, *connections*, and *flowpaths* define how processes are designed to *foster* improvement, Rule 4 defines the improvement process itself. This is extremely important because the efficiency and effectiveness of company's improvement process defines its ability to learn as an organization.

5.4.1 HOW IMPROVEMENTS ARE MADE

Spear and Bowen describe two key elements in organizational learning –*how* improvements are made and ***who*** makes them. The *how* is the classic scientific method of formulating a hypothesis and then proving (or disproving) it with observation. In Spear and Bowen's research, they identified that this method was used extensively throughout the Toyota Production System in both repetitive processes and improvement activities. Rather than the more common process of setting an arbitrary goal and attempting to achieve it, Toyota personnel are expected to propose well-defined changes and their estimated impacts (the hypotheses) along with explicit reasoning behind the expected results. For instance, rather than proposing an inventory reduction of 20% and then setting off to achieve this, an improvement group would research and propose a specific change in transportation logistics with an carefully estimated expected result. After implementation, the group compares the actual results with the expected results, using the comparison to learn about their improvement process and to reinforce their use of the scientific method. It is through this lessons-learned process that the organization solidifies its capability to learn.

Do external kanban systems promote the scientific method in this manner? In essence, they don't. While external kanban systems provide an environment that is ripe for use of the scientific method (unambiguous processes, immediate recognition of failures, direct connections), they do not encourage the organization to capitalize on these opportunities through improvement activities. Instead it is the culture and management of the organization that must create this.

The external kanban systems implemented at Ford-Saarlouis are a perfect example. By all counts, they contained all the characteristics necessary to promote improvement. They contained layout unique layout improvements and innovative process changes with could conceivably be applied throughout the plant. While these improvements definitely helped to improve understanding of how processes worked, we did not attempt to take advantage of these characteristics to promote learning throughout the plant. For instance, if a card were lost, a new one would be printed without learning exactly why the card was lost. Similarly, if a delivery was late, it was regarded as a one-time occurrence, unlikely to happen again. These occurrences should have been dealt with more as rejections of a hypothesis for card handling or on-time deliveries, and the failure of these hypotheses explored in more detail. Ford-Saarlouis was not gaining the true benefits from their external kanban systems.

5.4.2 WHO MAKES THE IMPROVEMENTS

Now that we know that improvements are made under the scientific method, we turn to *who* makes the improvements. The *who* is "the lowest possible level in the organization, under the guidance of a teacher" (Spear and Bowen, p 99). Clearly this indicates that employees are responsible for improvement of the processes which they use. For instance, this implies that assemblers are responsible for improving their own assembly process. For external kanban systems, it implies that the forklift drivers, receiving personnel, and suppliers are responsible for improving the process.

But these employees do not innately know how this is done. Clearly for these improvements to occur, these employees must be skilled in problem solving and process improvement techniques necessary to develop these improvements.

Spear and Bowen's clause "under the guidance of a teacher " identifies how employees gain the skills necessary to make improvements. The second *who* is the teacher. The teacher, who is usually a supervisor or group leader within the organization, instructs the employees in using the scientific method while employees are executing their improvement activities. For instance, the teacher can guide the group in forming hypotheses and projected results, a precursor to any improvement activities. Obviously the teacher must herself be experienced, well-trained, and willing to pass her knowledge on to others.

Do external kanban systems promote the role of the lowest level and the teacher in organizational learning? No. While the external kanban systems return control of logistics processes to those who work within the processes (i.e. receiving personnel, etc.), their operation does not promote these employees to attempt to improve the process. Similarly, external kanban systems have no effect on the role of a teacher in organizational learning

The fact that external kanban systems do not in and of themselves promote organizational learning was evident at Ford-Saarlouis. For instance, although the first external kanban system was had been operating for three months prior to my arrival, those operating the system were not attempting to improve it. Similarly, implementation of the first external kanban system did not immediately spurn other external kanban systems. Rather, because of a shortage of engineering personnel, implementation of other systems started after my arrival. Through the implementation of external kanban systems, an organization cannot expect to boost organizational learning.

5.5 SUMMARY

External kanban systems provide an environment for organizational learning, but do not themselves promote it. To provide this environment, external kanban systems encourage use of activities, connections, and flowpaths that are direct, predetermined, and unambiguous, as outlined by Spear and Bowen's work. What external kanban systems cannot provide is the structure and coordination of the improvement activities that are so critical to organizational learning.

KEY POINTS

- **By promoting activities, connections, and flowpaths that are direct and unambiguous, external kanban systems provide greater opportunity for improvement.**
- **External kanban systems themselves do not promote organizational learning. Only through systematic training and workforce development, can management improve an organization's ability to learn.**

SECTION 6: CONCLUSION

Through the implementation of external kanban systems at Ford-Saarlouis and the research completed on external kanban systems, many of the more subtle aspects of kanban systems become evident. First, it is evident that many of the benefits often associated with kanban systems come not simply from the kanban system itself, but from other aspects of the production system (such as production leveling and reduced setup times) which work in tandem with kanban systems.

Next, in looking for savings from external kanban systems, management should look past the easily measured labor, inventory, and transportation costs. While saving can and do often occur in these areas, they are generally not significant. Instead, management should look towards external kanban system's benefits of lowering overhead costs, specifically in the ordering, receiving, and accounting areas. These benefits provide far greater returns, both immediately and compounded through time. Although these savings are more difficult to quantify, understanding and maximizing them provides the greatest opportunity for realizing the full benefits of external kanban systems.

Another savings management should focus on is organizational learning. With highly specified activities, connections, and pathways, external kanban systems create a highly repeatable process in which each problem becomes a glaring opportunity for improvement. With control and communication largely in the hands of receiving employees and suppliers' personnel, improvements can be decided upon and implemented quickly. Of course, management must educate and motivate employees to capitalize on the opportunities external kanban systems provide, and to wring the maximum amount of learning from them.

In conclusion, the greatest savings from external kanban systems come from less well-defined aspects of the organization. While this shifts justification for external kanban systems from a decision of hard financial numbers closer to a leap of faith, it is a leap that can provide constant benefits for many years to come.

APPENDIX A: HISTORY OF KANBAN SYSTEMS

This appendix is intended for those readers interested in the history of kanban systems. Although this is only peripherally related to the subject matter of this paper, it does help to bring insight to the reasons and difficulties of developing and implementing external kanban systems.

DEVELOPMENT OF KANBAN AT TOYOTA

The year was 1948, just three years after the end of World War II and the nation of Japan was attempting to rebuild itself (Ohno, 1988). At Toyota Motor Company, a production manager Taiichi Ohno who was constantly looking to improve the productivity of his operations, began experimenting with a different material replenishment systems. Having seen how American supermarkets replenished their stock based on recent sales, Ohno recognized the simplicity of the process and began to apply it in his machine shop (Ohno, 1988, p. 33).

Five years later, Ohno had finally laid a rudimentary process in place. Development of the process had been punctuated by numerous failures and restarts but in these five years, Ohno and his organization had learned about the nuances and peculiarities of these new pull-type replenishment systems. What became obvious was that to reap the benefits from these systems required a great amount of organizational change. Machine change-overs needed to be sped up, high quality levels became extremely important, and the entire organization needed to operate both in a more standardized and a more flexible manner. Essentially, Ohno now saw his pull-type replenishment system had to lie within a much larger, more complex production system. This was the start of the Toyota Production System.

Toyota's Expansion of Kanban Systems to External Suppliers

Though the benefits were obvious (lower costs, greater labor flexibility, lower inventory levels), it took another fourteen years for these concepts to spread throughout Toyota. Employees had to learn new processes and procedures, equipment had to be modified and moved, and new hurdles, specific to each site, had to be overcome. In fact, it was not until 1961 that Toyota started to extend kanban replenishment systems outside of immediate plants. This was the start of *external* kanban systems.

This presented Toyota with new challenges. Not only did they now have to train individuals outside of their immediate employees, but also the rigidities of transportation methods and physical geography had to be overcome. As Shigeo Shingo, a consultant to Toyota at that time says:

> "This explains why, after twenty years of actual implementation in its own plants, it still took Toyota nearly ten years to create a comprehensive system that encompassed both Toyota Motors and its suppliers (Shingo, 1989).

In fact, in 1991, over thirty years after the introduction of Toyota's to North America, Toyota was just starting a major implementation of TPS and kanban systems in its US distribution centers (Womack, 1991, p. 74).

Expansion Throughout the Automotive Industry

While, by the mid-1960s Toyota had nearly all its factories and most of its suppliers operating on TPS and replenishing material using kanban systems, other manufacturers took little notice until 1973. It was then that the worldwide recession and *oil shock* decimated the income statements of nearly all automotive firms, including Japan's. Somehow, however, Toyota was able to maintain a much better financial position than its competitors. When the rest of the Japanese automobile industry began to realize this was largely the result of TPS, they immediately launched their own efforts to copy TPS.

Similarly, in the United States, the 1973 recession gave Toyota, which offered economical cars, a foothold into the American market. It rapidly became apparent to consumers and manufacturers alike, that not only were Toyota's cars less expensive, they were also more reliable. While the cost advantage was initially written off as an exchange rate anomaly, by the mid-1980's, rising exchange rates and the continued cost competitiveness of Japanese automobiles forced American producers to admit that the difference was largely one of productivity and efficiency. While manufacturers struggled to determine how to adapt elements of TPS to their organizations, in 1991, with the publications of The Machine That Changed the World, a comprehensive analysis of global automotive manufacturing revealed what everyone had suspected all along. Toyota, trailed by the Japanese firms who had followed its lead, was the manufacturing leader among almost all dimensions, including quality, cost and productivity.

What we see now, over 50 years since Taiichi Ohno first started to experiment with pull-systems at Toyota's machine shop, is the adoption of TPS element, including kanban systems worldwide. Many operations, having quickly adopted these principles, operate strictly on pull-type systems while others are just starting implementation now. At Ford-Saarlouis, where many of the quality and productivity aspects of TPS had been implemented years earlier, implementation of kanban systems has just begun within the last three years.

APPENDIX B: SYNCHRONOUS MATERIAL FLOW AT FORD-SAARLOUIS

Synchronous material flow (SMF) is the subset of the Ford Production System (FPS) which outlines the optimum material replenishment system. To implement SMF, a plant must go through three distinct phases. These phases are:

1. Stability – stabilizing internal processes such that employees are aware of proper procedures and can recognize when non-standard activities are occurring.

2. Pull-System – the implementation of pull-type material replenishment systems, such as kanban systems.

4. Level production – this refers to leveling demand for incoming parts that will be assembled to vehicles. As mentioned in Section 2.3.1 (page 21), this is necessary to minimize inventories and optimize material logistics.

STABILITY PHASE

At Ford-Saarlouis, the Stability Phase was well deployed. For instance, all operations had fully documented process sheets which outlined specific operation instructions, assembly times, and the equipment required. Tools and equipment were carefully labeled, monitored, and calibrated when necessary. Visually, the factory was always immaculate, a fact that made the extensive labeling of stock locations, assembly processes, and safety procedures stand out among the complex inner-workings of the plant. While certainly the plant will continue to improve the stability of its internal processes, they were already at world-class levels.

PULL-SYSTEM PHASE

The second phase, Pull-System, is of greatest interest to us; it is during this phase that kanban systems are implemented. The Pull-System phase deals with converting material replenishment logistics from traditional forecasted systems to pull-type systems (primarily kanban systems). These systems are traditionally separated into two categories, *internal logistics* for all material movements within the plant, and *external logistics* for material movement into and out of the plant. While the subject of this paper, external kanban systems, lies firmly within the external logistics category, external kanban systems must interact closely with internal logistics systems. In addition, Ford-Saarlouis had started implementing internal kanban systems internally before attempting external kanban systems, and so these systems served to familiarize the organization with the kanban system's basic elements. For this reason, a brief outline of Ford-Saarlouis internal pull-systems is provided in Appendix C: (page 97).

LEVEL PRODUCTION PHASE

Contrary to the first two phases, Ford-Saarlouis had only started implementation of the final Level Production phase. As mentioned before in Section 2.3.1 (page 21), leveled production is critical to reducing inventory levels using kanban systems. However, several times during the course of my internship, large variations in production occurred. Although this can be expected for some low volume parts with requirements of five or ten units per day, at Saarlouis the demand for even large, high volume modules, such as engines, fluctuated up to 40% from day to day. This, in turn, drove swings in the demand for many subordinate parts[20], causing significant variance in the daily requirement for each part. Of the three phases, Ford-Saarlouis had made the least progress on the Level Production phase.

[20] Subordinate Parts – subordinate parts are parts that attach to a module. For example, fuel lines and exhaust systems would be subordinate to the engine module, since different fuel lines and exhaust system would be required for different engine types.

APPENDIX C: INTERNAL KANBAN SYSTEMS AT FORD-SAARLOUIS

While *external* kanban systems control material replenishment between suppliers and an assembly plant, *internal* kanban systems distribute parts from internal marketplaces (storage locations) to their points-of-fit[21] (See Glossary, p. 106). Because internal systems must work in concert with external systems, understanding them helps to clarify the challenges and opportunities of implementing external kanban system.

At Ford-Saarlouis, *internal* logistics had undergone and enormous transformation during the 1998 launch of the Ford Focus. In this period, Ford-Saarlouis' Materials Planning and Logistics department has transformed nearly 50% of its parts to pull system, including training its entire workforce on Synchronous Material Flow (SMF) methods and wiring the plant for a simple but effective electric kanban system.

When designing their external logistics system, Ford-Saarlouis followed the Ford Production System's (FPS) rules and categorized parts into two types: 1) Card-parts and 2) Call-parts. Card-parts are small parts that fit into standardized, reusable totes and could be delivered by hand. Call-parts are large parts that could only be moved by forklift. This difference in handling forced the different types of parts to have two entirely separate internal logistic systems, both were pull-type kanban systems but each tailored to the specific needs of its different part types.

CARD PARTS

Card-parts, small parts that can be moved by hand, make up over 80% of the parts used at Ford-Saarlouis. Before 1998, these parts were moved, stored, and used primarily in full pallet loads. Typically a full pallet load consists of fifteen to thirty smaller totes strapped together to make a one-meter square block which could be moved with a forklift.

Figure 11: Card part in totes nested to create a complete pallet.

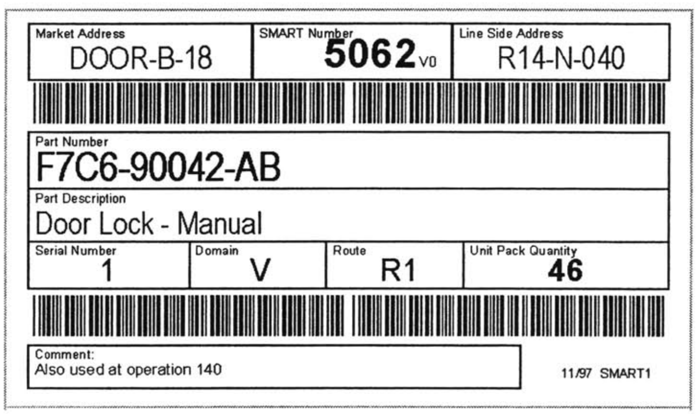
Prior to implementation of the card system, Ford-Saarlouis distributed these parts to the points-of-fit (on the assembly line) in full pallets. This handling of only full pallet loads had multiple drawbacks. First, full pallets cause significant congestion at the points-of-fit, making it difficult to access the parts and taking up valuable space for the assembly line operator. Second, these pallets often required unpacking and re-handling at the points-of-fit, to orient the part so they are accessible by the operator. Finally, if a part had a low usage rate, a full pallet could constitute many days, weeks, or even months of inventory, far more than was necessary at the point-of-fit.

To address these issues, Ford-Saarlouis implemented a pull-type material replenishment system called their Card-system. In this system, card-parts were still delivered from vendors in full pallets. However, after receiving the pallets, Ford-Saarlouis personnel moved the parts from the loading dock to a warehouse-like marketplace adjoining the plant. In this marketplace, the full pallets were broken down into individual totes and the totes were placed on a pre-assigned, *first-in, first-out*, rolling rack. Because the full pallets were not delivered directly to the points-of-fit, vendors were allowed to mix different part types on a single full pallet. This, in turn, reduced the amount of inventory at Ford-Saarlouis.

[21] Point-of-Fit - The location on the assembly line where parts are assembled onto a vehicle. In the logistics distribution chain, this is the ultimate destination for parts assembled to vehicles.

Figure 12: Card parts in first-in, first-out racks.

From the marketplace, Ford-Saarlouis ran an *internal, withdrawal-type, constant-order-cycle kanban* (reference Section 2.3, page 27). Every two hours, a tractor driver would drive a fixed route through the plant distributing totes of card-parts, each of which contained a kanban card (hence the name, card-part).



Market Address: DOOR-B-18
SMART Number: 5062 VD
Line Side Address: R14-N-040
Part Number: F7C6-90042-AB
Part Description: Door Lock - Manual
Serial Number: 1
Domain: V
Route: R1
Unit Pack Quantity: 46
Comment: Also used at operation 140
11/97 SMART1

Figure 13: Kanban card used with call part.

When the assembly line operator used a full tote of parts, he would remove the kanban card and place it in a specified mailbox. As the driver distributed parts, he would simultaneously pick up the *used* cards from the mailbox. He would then return to the marketplace and use these *used* cards as his next order to be delivered.

Figure 14: Carts used to distribute card parts to points-of-fit.

With the addition of the card-system, Ford-Saarlouis was able to solve many of their prior problems of excessive stock on the assembly line, visual verification of inventory levels, and more frequent receipt of low-utilization parts. With the amount of stock on the assembly line now strictly controlled by the number of kanban cards in use, they also had complete control over the amount of inventory between the marketplace and the point of fit. By delivering card parts to the assembly line every two hours, Ford-Saarlouis was able to reduce the lineside inventories from days or weeks to just over two hours (although inventory in marketplaces, in-plant storage locations, was not reduced).

CALL-PARTS

Call-parts are parts that, due to their size or weight, required a forklift to move them. This includes about 20% of the Ford-Saarlouis' parts, including interior parts, window glass, brake components, etc. The vast majority of these parts were delivered in a one-meter cube reusable plastic container, called a Chep container.

Figure 15: Typical Call Part in Chep Container

Prior to the implementation of the call-system, a kanban system for call-parts, forklift drivers were assigned responsibility for material replenishment of fixed section of the assembly line. They would then constantly cruise this section looking for parts in need of replenishment. Once he identified a part for replenishment, the driver would then travel to that part's marketplace (which was not necessarily always in a fixed location), pick up a pallet of the parts, deliver it, and remove the empty container.

For a skilled driver with a strong rapport with the line operators, this worked reasonably well. However, it had numerous drawbacks. First, it kept forklifts cruising the aisles, increasing the likelihood of an accident or safety incident. Second, in the case that the assembly line runs out of two parts at one time, the driver would have to scramble to replenish both parts simultaneously. Finally, because of the lack of dedicated marketplace locations for stock storage, confusion over the location of stock was common.

To replace this, Ford-Saarlouis installed the card-system, an *internal, withdrawal type, constant-order-quantity kanban system*. In this system, a push-button switch was installed at all points-of-fit. When the assembly line operator required parts, he would push this button. This would then send a signal to a remote *call-board* and light a light next to a pocket holding the parts kanban card. The forklift driver would pick up this kanban card, which contained all of the reordering information (part number, marketplace location, point-of-fit), drive to the part's marketplace (as specified on the card), pick up a pallet of the required parts and deliver it to the point-of-fit. The driver would then return the card to the call-board and wait for the next request for parts.

Adoption of the call-system has replaced a haphazard replenishment process with a well-defined and controlled process. In doing so, Ford-Saarlouis has been able to increase their driver utilization and productivity while reducing the number of stock-outs due to errors by the line feeders.

BIBLIOGRAPHY

1. Automotive News '99 Market Data Book (May 1999), Crain Communications. This annual guide to the automotive industry provides detailed statistics on sales, production, quality, etc., broken down by manufacturer and by vehicle platform.

2. "1999 Automotive Industry Report Card", Automotive Industries (April 1999), p. 31-35. This annual summary for the automotive industry provides statistics and commentary on the performance of automotive manufacturers including quality, costs, technology, and production.

3. "Ford 1999 Worldwide Plant Guide" (1999). This reference brochure lists statistics for all of Ford Motor Company's plants worldwide.

4. "Harbour Report – Europe" (1999). This is the final presentation on automotive assembly plant productivity given by Harbour and Associates to Ford. The analysis includes all major automotive manufacturers and gives both relative and actual productivity levels for each plant. Because specific productivity statistics are confidential, only information on the relative performance of plants has been used in this thesis.

5. "Logistik: Konzept für das 21. Jahrhundert", Automobil Produktion, Januar 1999, pp. 68-72. This article summarizes the logistics strategy of Ford-Saarlouis at time of the Ford Focus launch. The article covers the thinking behind logistics concepts such as the Supplier Park, Synchronous Material Flow, and internal delivery systems.

6. Monden, Yasuhiro (1997), Toyota Production System: An Integrated Approach to Just-In-Time, Engineering Management Press, 1997 (Third Edition). This book focuses on the mechanics of the TPS and delves into details such as production-leveling algorithms and the layout of capacity planning sheets. The comprehensiveness of this book clearly demonstrates that many systems (including kanban) are necessary to make TPS implementation successful.

7. Ohno, Taiichi (1988), Toyota Production System, Beyond Large-Scale Production, Productivity Press, 1988. This book provides an overview of the history and basic theory behind TPS. Because it is written by one of the original founders of TPS, this book provides keen insight into the high leverage points necessary to implement a successful kanban system.

8. Schmitt, Hans Günter (1997), "Information über Ford in Deutschland: Das Gaschäftsjahr 1997, Standorte, History", 1997. This brochure provides general information about the history, culture, and products of Ford of Germany.

9. Senge, Peter, The Fifth Discipline, The Art and Practice of the Learning Organization, Doubleday, 1990. This book outlines the authors vision of how a organization learns and recommends ways to promote it within all organizations..

10. Shiba, Graham, and Walden (1993), A New American TQM: Four Practical Revolutions in Management, Productivity Press, 1993. This book outlines the methods and benefits of applying total quality management techniques to modern American corporations.

11. Shingo, Shigeo (1989), A Study of the Toyota Production System, Productivity Press, 1989 (Revised Edition). As a consultant to Toyota during the development of TPS, Shigeo Shingo was able to see first-hand how the system developed. While his book covers many of the general characteristics of TPS, it focuses most heavily on the importance reducing setup times and single minute exchange of dies (SMED), which he was instrumental in promoting in Japan.

12. Spear, Steven (1999), "The Toyota Production System: An Example of Managing Complex Social/Technical Systems. Five Rules for Designing, Operating, and Improving Activities, Activity-Connections, and Flow-Paths.", Doctoral Thesis, Harvard Business School, 1999. This is thesis covers in detail the development and research behind the concepts in Spear and Bowen (1999) listed below. It details the less-than-obvious organizational structure and ingrained improvement processes that are key to the long-term success of the Toyota Production Systems.

13. Spear, Steven and Bowen, Kent (1999), "Decoding the DNA of the Toyota Production System", Harvard Business Review, September-October 1999, pp. 97-106. This article describes the fundamental factors that make TPS so successful. While kanban systems are only one small part of TPS, they serve as a clear example that supports the conclusions of this research.

14. Steffens, F. (1999), "Pay on Production (PoP), Process with CMMS3 for BAO", Internal Ford Document, 26 March 1999. This document outlines the prerequisites, procedures, and benefits for implementing pay-on-production supplier payment schemes at Ford.

15. Sterman, John D. (1998), Business Dynamics: Systems Thinking and Modeling for a Complex World, Partial Draft, Ver. 1.1, August 1998. This preliminary text outlines the use of systems dynamics for modeling business systems, including manufacturing supply chains.

16. "The Toyota Production System" (1992), Toyota Motor Corporation, International Public Affairs Division, 1992. This brochure is part of the materials used by Toyota Motor Corporation when training new employees. It provides a simple, clear overview of TPS.

17. Womack, James P. and Jones, Daniel T. (1996), Lean Thinking, Banish Waste and Create Wealth in Your Corporation, Simon & Schuster, 1996. This book focuses on implementation of *lean manufacturing* (which incorporates the elements of TPS) from a managerial perspective. The book contains numerous examples of implementation from companies throughout the world.

18. Womack, James P. and Jones, Daniel T. and Roos, Daniel (1990), The Machine That Changed the World, Rawson Associated, New York, 1990. This groundbreaking book provided a comprehensive overview of the history of automotive production up until 1990. Of greatest importance is its outstanding comparison of the American, European, and Japanese production systems.

19. "Zulieferpark: Synergien durch Nachbarschaft", Automobil Produktion, Januar 1999, pp. 86-88. This article describes the business relationship between Ford and its suppliers in the industrial park connected to the Ford-Saarlouis plant. Of particular importance is the creation of logistics companies that receive,

prepare, and deliver large parts (instrument panels, headliners, etc.) in cooperation with the part manufacturer.

GLOSSARY

Advanced Shipping Notice (ASN) - an advanced shipping notice is an electronic document transmitted by a vendor to Ford in advance of the vendor's delivery. This document allows Ford to be prepared for receipt of the material, significantly expediting the receiving process.

Constant Order-Cycle System – a replenishment system which reorders material a defined number of times. The quantity of material reorder is inconsistent and depends on the quantity of material used in the prior time period (Monden, 1997, p. 316).

Constant Order-Quantity System – a replenishment system that reorders material after a specific amount has been consumed. Although the quantity reordered is always the same, the time between reorder points fluctuates depending on material consumption rate (Monden, 1997, p.316).

CMMS – Ford Motor Company's homegrown Material Requirements Planning (MRP) system. CMMS operates in nearly all of Ford's plants worldwide to plan production, track inventory, schedule orders, and coordinate information for nearly all other tasks in the manufacturing plants.

Cube-Utilization – the percent of a trailer's volume filled with material during a delivery. A reasonable average cube-utilization for an automotive logistics provider is 80%.

Demurrage – payments from a receiver of goods to the transportation company for use of a truck trailer. Most often these charges result when the receiver is unable to unload the trailer at the proper time, thus precluding the transportation company from using the trailer for another delivery.

External Kanban System – Same as a supplier kanban system. A kanban system which operates between a consumer (e.g. factory) and an externally located supplier.

ERP (Enterprise Resource Planning) Systems – See MRP Systems.

Ford Production System – Introduced in 1994, this is Ford's attempt to modernize its manufacturing operations operating procedures. It is expected to take many decades to fully rollout through the organization. Production systems are the explicit and implicit rules which guide the manufacturing organization's actions (such as material replenishment), decisions (such as when to produce), and culture.

Lead Logistics Partner (LLP) – A logistics firm that coordinates the delivery of material to the plant. The LLP works closely with the manufacturing plant to communicate with suppliers and transportation providers, determine and monitor delivery schedules, and implement improvement to the external logistics system.

Later Replenishment – Also called a Substitution Order Format. This is the principle behind material replenishment systems that reorder material based on what has been consumed. Supermarket and kanban replenishment systems are based on this principle (Monden, 1997, p. 43).

Marketplace – A storage location within the assembly plant for material waiting to be delivered to the point-of-fit (where it is assembled to the vehicles). A *marketplace* exists for each part number so that parts can be found when needed and that inventory levels can be easily verified.

Meldestelle – this is a receiving location on the periphery of the Ford-Saarlouis Assembly Plant. Before all trucks entered the plant's grounds, they had to stop at the Meldestelle to verify and approve their paperwork. Literally translated, Meldestelle means *communications place.*

MRP (Manufacturing Resource Planning) – A manufacturing control system which expands manually generated forecasts, into daily or weekly production requirements. This is done by powerful computers combining forecast information with bill-of-materials, capacity information, part process requirements, etc. to calculate the process timing of a part moving through the manufacturing operations. MRP systems that have been expanded to include financial, accounting, and marketing data may be called ERP (Enterprise Resource Planning) systems.

Pay-on-Production (PoP) – A payment method which effectively transfers ownership of raw materials and parts to Ford only after those parts are assembled into a vehicle *and* the vehicle is shipped (i.e. parts used by the plant are paid for when vehicles leave the plant). This payment scheme simplifies plant inventory management, bookkeeping, and vendor payment records significantly.

Point-of-Fit – The location on the assembly line where parts are assembled onto a vehicle. In the logistics distribution chain, this is the ultimate destination for parts assembled to vehicles.

Production-ordering Kanban – A kanban that defines the quantity of material the preceding (*upstream*) process must produce (Monden, 1997, p. 6).

Sequenced Withdrawal – Also called *Sequenced Delivery.* Ordering and receiving material in the projected production sequence. For instance, automotive manufacturers typically order and receive seats *in-sequence* to minimize in-house inventory of these bulky items.

Substitution Order Format – Also called *Later Replenishment* format. This is the principle behind material replenishment systems that reorder material based on what has been consumed. Kanban systems and supermarket replenishment systems are based on this principle (Shingo, 1989, p. 178).

Supplier Kanban System – Same as an external kanban system. A kanban system which operates between a consumer (e.g. factory) and an externally located supplier.

Synchronous Material Flow (SMF) – SMF is the name of the materials replenishment concepts contained within the Ford Production System. These concepts include process stability, pull systems, and production leveling.

Toyota Production System (TPS) – The production system developed by Toyota to run their operations. First initiated in 1948, TPS is highly developed and is currently thought of the most competitive system in automotive manufacturing. Production systems are the explicit and implicit rules which guide the manufacturing organization's actions (such as material replenishment), decisions (such as when to produce), and culture.

Withdrawal Kanban – A kanban which defines the quantity which the subsequent (downstream) process must withdrawal (Monden, 199, p. 6).