MODELLING KANBAN PULL SYSTEMS WITH ADVANCE DEMAND INFORMATION

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This paper investigates the benefits of integrating Advance Demand Information (ADI) with pull-kanban type Production and Inventory Control Systems (PICS). We investigate the impact of several PICS design parameters such as kanban card limits, target finished goods inventory levels, amount of demand information available, and the quality of ADI on performance measures such as system throughput, inventory holding costs and customer service levels. Our study shows that in many situations, integrating ADI with pull systems provides opportunities for efficiencies that might be significantly greater than available using pull systems alone. Furthermore, we show that the performance of systems operating under pull-type PICS with ADI could be fairly robust to the quality of information being shared.

Keywords: Advance Demand Information (ADI), Production and Inventory Control System (PICS), Kanban Pull.

INTRODUCTION

The Production industries have seen a dramatic change away from high product throughput and high capacity loads towards lower production lead times and work-in-process inventory. Pull-type production control aims at reducing costs through keeping the work-in-process (WIP) inventory at a minimum level and thus improving the company’s ability to adapt to changes, e.g., demand and production fluctuations.

Kanban systems are often used to implement the pull-type control in production systems. Nowadays industries are responding to the challenge of e-commerce and customer ordering via the Internet by shifting to re-configurable manufacturing equipment and a make-to-order environment. Traditional mass production manufacturing is not particularly responsive to changing customer demands, for it relies on forecasting future demand and scheduling the release of work into the system to meet expected demand. Mass production systems often have excess inventory, higher WIP levels, and longer quoted lead-times from order to delivery. In contrast, just-in-time production relies on actual demand triggering the release of work into the system, and “pulling” work through the system to

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fill the demand order. Just-in-time production is better able to respond to changing customer demands, for as a production philosophy, it advocates producing the right products at the right times and in the right amounts.

This research focuses on one important aspect of the benefit of information sharing - namely the sharing of Advanced Demand Information (ADI) to improve supply chain efficiencies. In particular, it focuses on how ADI can be integrated with the Production and Inventory Control Systems (PICS) being adopted on the factory floor to improve operational efficiencies. Factory operations are complex and the efficiency of operations is sensitive to several factors such as machine utilization, inventory limits, and promised levels of customer service (Buzacott and Shanthikumar, 1993). Hence, it is hard to develop an intuition for PICS that would yield good performance. Over the last few decades, several PICS have been proposed to efficiently manage production resources, eliminate wasteful inventories, and improve customer service levels. Among these the most popular ones are the pull-type PICS such as base stock system, kanban system, and CONWIP. These systems have been successfully implemented in several industries and have therefore been the focus of several research studies too. However, none of the above mentioned pull-type PICS fully exploit the potential benefits of ADI shared across supply chains. A recent study by Karaesman et al. has shown that integration of ADI with base-stock-type control policies could lead to significant improvement in efficiencies. Our research compliments this study by investigating the performance of PICS that integrating ADI with kanban type pull systems. In particular, we investigate the impact of design parameters such as target WIP levels or kanban card limits, target finished goods inventory levels, demand information lead times, and the quality of advance demand information on different performance measures. Since efficient analytical models that permit such a study are not yet available. Our study provides several insights with respect to the impact of integrating ADI with pull type PICS. We observe that in many situations, such integration provides opportunities for efficiencies that are greater than that possible using pull systems without ADI.

**PULL SYSTEM AND PULL SYSTEM**

**Push System**

The push system of inventory control involves forecasting inventory needs to meet customer demand. Companies must predict which products customers will purchase along with determining what quantity of goods will be purchased. The company will in turn produce enough product to meet the forecast demand and sell, or push, the goods to the consumer. Disadvantages of the push inventory control system are that forecasts are often inaccurate as sales can be unpredictable and vary from one year to the next. Another problem with push inventory control systems is that if too much product is left in inventory. This increases the company’s costs for storing these goods. An advantage to the push system is that the company is fairly assured it will have enough products on hand to complete customer orders, preventing the inability to meet customer demand for the product. An example of a push system is Materials Requirements Planning, or MRP. MRP combines the calculations for financial, operations and logistics planning. It is a computer-based information system which controls scheduling and
ordering. It's purpose is to make sure raw goods and materials needed for production are available when they are needed.

Pull System
The pull inventory control system begins with a customer's order. With this strategy, companies only make enough product to fulfill customer's orders. One advantage to the system is that there will be no excess of inventory that needs to be stored, thus reducing inventory levels and the cost of carrying and storing goods. However, one major disadvantage to the pull system is that it is highly possible to run into ordering dilemmas, such as a supplier not being able to get a shipment out on time. This leaves the company unable to fulfill the order and contributes to customer dissatisfaction. An example of a pull inventory control system is the just-in-time, or JIT system. The Kanban system plays very important in implementing the JIT system. The goal is to keep inventory levels to a minimum by only having enough inventory, not more or less, to meet customer demand. The JIT system eliminates waste by reducing the amount of storage space needed for inventory and the costs of storing goods.

Pull Vs. Push System
The key differences between pull and push systems are Pull is to make to order, while Push is make to stock. Pull production systems are usually compared to the Push system of production where production is pushed from one operation to the next through the factor whether the product is needed or not. The pull system is the center of any synchronized factory, it works by working backwards, using signals or cards to trigger or start production. The process starts at the finished products warehouse or the shipping area. When a customer orders a product, the process triggers the previous operation to replace it; signaling more products is needed. The process continues backward through the factory to where raw materials are withdrawn which in turn triggers the supplier to ship the raw materials.

PULL SYSTEMS: KANBAN
Kanban, meaning card or marker in Japanese, is the more widely known and recognized type of pull system. A Kanban pull system is sometimes referred to as the Toyota Production System (just-in-time manufacturing using a Kanban pull system) (Monden, 1981a).

A Kanban pull system uses card sets to tightly control Work-In Progress (WIP) between each pair of workstations. Total system WIP is limited to the summation of the number of cards in each card set. Production occurs at a workstation only if raw material is available and the material has a card authorizing production. Material is pulled through the system only when it receives card authorization to move. Figure 1 illustrates a serial Kanban system. Each Kanban card set between workstations authorizes material to be pulled into the upstream workstation for processing and delivery to the downstream workstation.
The concept of pull in Lean production means to respond to the pull or needs of customers. Lean companies design their operations to be more responsive to the varied and changing needs of their customers. Lean companies that are able to create such an operation can avoid the more traditional batch-and-queue method, which is generally acknowledged to be the worst way to process material through a factory. A more continuous flow results in items being moved immediately from one workstation to the next as soon as they are ready. Planning for the delivery of a product to customers becomes more efficient and demand from customers becomes more stable. The word Kanban is Japanese for instruction card or sign board. The Kanban is used to signal the need for replacing or refilling materials necessary for production. There are a variety of ways that the signal can be sent. Actual cards, that accompany goods through the production process can be used to keep track of current inventory. However, something as simple as the arrival of an empty container at an upstream processing station is a clear signal that the parts that were in the container have been used and more are needed. Kanban can be used in manufacturing systems where the product is manufactured to the pull of market demand.

A Kanban card can be generated to identify production of part(s) to replenish in-house inventories, a withdrawal of product for shipment to a customer, or to signal the replacement of raw materials and components. Using Kanbans there must be a purchase or an order to generate the card. The Figure 2 shows how the Kanban Pull System how the product is pulled through the production sequence based on the order from the customer.

Pull/Kanban is a part of the Lean Production or Just-in-Time (JIT) manufacturing process, applying Lean principals to eliminate waste. Every method in the Lean production system focuses on the elimination of waste. Lean principals should not be limited only to manufacturing operations, all areas of a company can benefit from the application of Lean principals. Reduction of waste ensures lower costs, higher quality products, and better service and delivery.

The key differences between pull and push systems are Pull is to make to order, while Push is make to stock. Pull production systems are usually compared to the Push system of production where production is pushed from one operation to the next through the factory whether the product is needed or not. The pull system is the center of any synchronized factory, it works by working backwards, using signals or cards to trigger or start production. The process starts at the finished products warehouse or the shipping area. When a customer orders a product, the process triggers the previous operation to replace it; signaling more products is needed. The process continues backward through the factory to where raw materials are withdrawn which in turn triggers the supplier to ship the raw materials.
WHY CONTROL WIP?
Manufacturers have found several advantages in controlling WIP. A finite WIP capacity limits the amount of material released into the system, allowing orders to stay on paper instead of as physical material on the production floor. Production systems have a degree of flexibility that is lost when large volumes of WIP are in the physical system. Keeping orders on paper until actual production occurs facilitates execution of scheduling and design changes. Scrapping product due to a design or engineering change can be costly, especially to a company with large amounts of WIP in the system. By controlling WIP, the amount of material that needs to be scrapped or reworked is reduced, and financial losses from sales of a now inferior product are diminished. A second advantage of WIP control is a reduction in cycle time variability. Referring to Little’s Law (WIP = Cycle Time * Arrival Rate), if the arrival rate is held constant, as the level of WIP increases, the cycle time must also increase. Push systems allow the possibility of large WIP buildups, causing high variability in cycle time plus increased costs in terms of inventory buildup. Increased variability in cycle time forces companies to quote longer lead-times in order to achieve the same level of customer service. Limiting WIP reduces the variability in cycle time while allowing the pull system to still achieve the same throughput level with less WIP than a push system. To accurately quote a time from order to delivery in a pull system, the time should include both the time that the order spends on paper and the actual time in the physical production system.

DIFFERENT TYPES OF KANBAN SYSTEMS
Withdrawal Kanban
The purpose of a withdrawal kanban is to pass along authorization for the movement of parts from one stage to another. The kanban starts with getting the parts from a preceding process, moving them to the next process and remaining with those parts until they have been consumed by that process. Then the cycle starts again. The information on a kanban includes a part number, part name, lot size, routing process, name or location of the next process, name or location of the preceding process, container capacity and number of containers released, according to Beyond Lean at beyondlean.com.

Production Kanban
A production kanban specifies what a preceding process must produce as far as type and quantity. The card also provides information on where that item should be sent when finished.

Emergency Kanban
An emergency kanban is for carrying out rush jobs given a high priority. These cards will typically be colored red, so an operator with a stack of cards can spot it and carry it out first.

Express Kanban
Companies use an express kanban when they encounter a shortage of parts. They withdraw the kanban after they have used it. The kanban prompts workers to switch on the machine for making the part and activate a light, which further prompts another worker to immediately produce the part and deliver it to the subsequent process.

Through Kanban
There is no need for multiple kanbans when two or more work centers are located near each other. Instead, a production line will only use one card known as a through kanban, where one process directly feeds the next process.
PRINCIPLES OF IMPLEMENTATION OF KANBAN SYSTEM

The main principles for the implementation of Kanban systems are as follows

Level production (balance the schedule) in order to achieve low variability of the number of parts from one time period to the next

Production leveling, also known as production smoothing or by its Japanese original term heijunka is a technique for reducing the muda (waste). It was vital to the development of production efficiency in the Toyota Production System and lean manufacturing. The goal is to produce intermediate goods at a constant rate so that further processing may also be carried out at a constant and predictable rate. On a production line, as in any process fluctuations in performance increase waste. This is because equipment, workers, inventory and all other elements required for production must always be prepared for peak production. This is a cost of flexibility. If a later process varies its withdrawal of parts in terms of timing and quality, the range of these fluctuations will increase as they move up the line towards the earlier processes. This is known as demand amplification. Where demand is constant, production leveling is easy, but where customer demand fluctuates, two approaches have been adopted: 1) demand leveling; and 2) production leveling through flexible production. To prevent fluctuations in production, even in outside affiliates, it is important to minimize fluctuation in the final assembly line. Toyota’s final assembly line never assembles the same automobile model in a batch. Instead, they level production by assembling a mix of models in each batch and the batches are made as small as possible. This is in contrast to traditional mass production, where long changeover times meant that it was more economical to punch out as many parts in each batch as possible. When the final assembly batches are small, then earlier process batches, such as the press operations, must also be small and changeover times must be short. In the Toyota Production System die changes (changeovers) are made quickly In the 1940s changeovers took two to three hours, in the 1950s they dropped from 1 h to 15 min, now they take 3 min.

Avoid Complex Information and Hierarchical Control Systems On a Industry

A Hierarchical control systems is a form of control system in which a set of devices and governing software is arranged in a hierarchical tree. When the links in the tree are implemented by a computer network, then that hierarchical control system is also a form of networked control system. Its recommended that always avoid the complex information and hierarchical control system on a industry which creates the nascent stage where the stages suffer from confusion on which information to prefer and follow. In such case following the kanban pull system will become more complex and difficult.

Do not Withdraw Parts without a Kanban

Do not allow any associate within the production site to withdraw the parts without the kanban card. Create a strict environment where everything must and should follow the kanban pull system. Whenever we try to avoid kanban system and pull the component which affects the system. For example consider when a associate withdraw raw materials from stores without kanban card a
mismatch exists between raw materials and finished goods. Which may create lots of problems in the future. To avoid such problems be strict in implementation of kanban system.

Withdraw only the Parts Needed at Each Stage
In every stage of production withdraw only the parts which are needed at each stage of production. Do not include any additional parts along with the required parts in an production line. Withdraw of unneeded parts at each stage which creates hidden problems of muda and mura. Which may affects the current existing pull system performance and damages the production.

Do not send Defective Parts to the Succeeding Stages
When implementing the kanban pull its very essential to ensure that no defective parts sent to succeeding stages. Sending the defective parts to the succeeding stages will increases the rejection of finished goods. If any parts are found to be defective at any stage of the production just send that parts back to inspection along with description of defective of the part. Which avoids the rejection of finished goods.

SUMMARY AND CONCLUSION
This paper presented a heuristic design methodology to determine the kanban allocation in complex production systems, here we used experiments to investigate the performance ADI with pull kanban type systems. We studied the impact of several design parameters such as kanban card limits, target finished goods inventory levels, and the amount of demand information available on various performance measures. Our study showed that in many situations, integrating ADI with pull systems provides opportunities for efficiencies that might be significantly greater than that available using pull systems alone. Furthermore, we also showed that the performance of systems operating under such PICS could be fairly robust to the quality of ADI being shared, particularly with respect to the variance in the demand information lead times. Our ongoing research involves investigating the performance of pull systems with ADI in the presence of other imperfections in quality of information.

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