JOB SEQUENCING & WIP LEVEL DETERMINATION IN A CYCLIC CONWIP FLOWSHOP WITH BLOCKING

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ABSTRACT

CONWIP (Constant Work in Process) is the material within the system undergoing transformation into a final product, and cycle time is the average amount of time required for raw material to be converted into a final product. Insufficient throughput leads to unmet demand. Excessive WIP requires tying up excessive capital. Excessive cycle time leads to the loss of customer orders. In short, if any of these parameters are not managed properly, then the manufacturing industry loses money. These parameters are influenced by process variability, process time, process reliability, system bottlenecks, and the production control system used. Manufacturing industries are required to focus and manage their system’s throughput, WIP, and cycle time. Here, throughput is the number of final products produced per unit time by the system. Managing the bottlenecks effectively and efficiently yields higher system throughput. Many production control systems have been proposed to improve throughput in the past. Among them following are constraints used by the manufacturing industries are the Materials Requirement Planning (MRP), Just-in-Time (JIT), Kanban (developed by Toyota Japan), Constant Work in Process (CONWIP), and Drum Buffer-Rope (DBR) systems.

In this process an analysis made of bottlenecks and their impact on throughput, work-in-process (WIP), and cycle time in manufacturing systems where three parallel production lines feed components into an assembly line is carried out. The goal of these works is to determine optimal settings of control parameters within the production control systems, and selecting the appropriate production control systems for different manufacturing environments. Among the manufacturing control systems push and pull systems are important systems which tell material is released into the production facility depending upon demand forecast. And the material is released into the system only when it is needed, these control system are also called JIT systems. CONWIP come under the JIT systems. The basic findings of the production line analysis is that under any pure production control system increasing the number of
bottlenecks generally increases WIP, and cycle time, and decreases throughput. According to Utilizing Little’s law given constant WIP and increased cycle time results in decreased throughput, and given constant throughput and increased cycle time results in increased WIP. Through the analysis performed shows the flow lines are constant by managing the assembly system with a push system; nonbottleneck flow lines with a pull system, the WIP of the system can be reduced. If the bottleneck station does not shift between flow lines, management of all feeder lines with CONWIP systems can result in higher system throughput and reduced system WIP.

Key words: Cyclic CONWIP, WIP Level, Job, MRP, JIT

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1. INTRODUCTION

The primary goal of manufacturing is to make profit in the present and in the future. Accomplishing this goal has been a daunting challenge for manufacturing managers since the dawn of time. There are many obstacles in a manufacturing enterprise that prevents management from accomplishing this goal. The Theory of Constraints (TOC) is a management philosophy proposed by Goldratt that deals with managing system constraints or bottlenecks. The five-step methodology focuses on identifying the system constraints, exploiting the constraint, subordinating the rest of the system to the needs of the constraint, improving the constraint, and repeating the process continually. In a factory the bottlenecks are usually those machines or processes which control the throughput of the system. Managing the bottlenecks effectively and efficiently yields higher system throughput. Many production control systems have been proposed to improve throughput in the past. Among them are the Materials Requirement Planning (MRP), Just-in-Time (JIT), Kanban, Constant Work in Process (CONWIP).

Successful manufacturing centers are required to identify and manage their system’s throughput, WIP, and cycle time. Here, throughput is the number of final products produced per unit time by the system, WIP is the material within the system undergoing transformation into a final product, and cycle time is the average amount of time required for raw material to be transformed into a final product. Insufficient throughput leads to unmet demand. Excessive WIP requires tying up excessive capital. Excessive cycle time leads to the loss of customer orders. In short, if any of these parameters are not managed properly, then the manufacturing center loses money. These parameters are influenced by process variability, process time, process reliability, system bottlenecks, and the production control system used.

Recent work has investigated how bottlenecks affect a system’s throughput, WIP and cycle time in relation to different control methodologies. The goal of these works is to determine optimal settings of control parameters within the production control systems, and selecting the appropriate production control systems for different manufacturing environments. The current manufacturing control systems may be classified into three categories. The first is MRP and its successor Manufacturing Resource Planning (MRPII). These control systems push materials into the production facility based on forecasted demand, and are thus known as push systems. In the second category of control systems, known as pull systems, the material is released into the production facility only when the demand for the end product triggers it. Since the material is released into the system only when it is
needed, these control systems are also called JIT systems. The two popular implementations of JIT control systems are Kanban (card) control systems and CONWIP control systems. In all JIT systems the WIP is controlled by the number of authorization cards assigned to the individual workstations or system of stations. The third category of control systems is mixed control systems. In these systems, the pull and push control systems are used to manage certain segments of the production line. Examples of mixed control systems are DBR, pull-push and push-pull control systems.

2. MANUFACTURING INVENTORY CONTROL SYSTEMS

There are two primary manufacturing control systems: push and pull systems. All other control systems are either combinations or derivatives of these two systems. In manufacturing systems finite storage space plays an important role for receiving raw material and completed units. So, Manufacturing control systems manage how products are passed on, how buffers are utilized, and when raw material enters the system. The buffers (storage space) act as a safety net to guard against line starvation and blockage caused by random events.

3. PUSH CONTROL SYSTEMS

“Push” control systems utilize forecasted demand to determine a production schedule. The production schedule sets when raw material is delivered to the appropriate workstations. Each workstation provides the necessary processing to the units waiting in its buffer prior to releasing it to be transferred to the next downstream station. This cycle of receiving, processing and releasing of material is carried out until the end product is complete. In a push control system shipping of goods downstream is independent of the downstream stations’ condition. This independence can cause problems if the downstream station is offline. If the downstream station is offline, the WIP in the system escalates until the station is online again. The WIP may or may not decrease at this time.

![Figure 1 Push Systems](image-url)

"Push type" means make to Stock in which the production is not based on actual demand. In supply chain management, it is important to carry out processes halfway between push type and pull type or by a combination of push type and pull type. The diagram fig1 refers to the movement of the product through the system. Since the production schedule represents demand information, the quantity of moving products represents the movement of information in the system.
4. PULL CONTROL SYSTEMS

"Pull type" means make to Order in which the production is based on actual demand. This process of release and material procurement is repeated throughout the system until the raw material of the first station is obtained. Since product movement is dependent on the condition of the next station, the entire production line may stop due to the breakdown of an upstream station.

![Pull Systems Diagram](image)

The solid and dashed arrows in the diagram respectively refer to the movement of the products and information. Since the cards represent demand information, the movement of information represents the movement of information in the system. Unlike the push system, demand information originates in the final station and proceeds to the initial station.

One of the major reasons why supply chain management currently receives so much attention is that information technology enables the shifting of a production and sales business model from "Push type" to "Pull type". Pull-type supply chain management is based on the demand side such as Just-in-Time (JIT) and CRP (Continuous Replenishment Program) or actual demand assigned to later processes. Therefore, unlike the Push-type method it is not make to Stock, which is based on demand forecast. While inventory is kept to a minimum, products can be supplied with short lead times and at high speed. At the point where "Pull type" starts to supply operations triggered by actual demand, it is like an elevator. An elevator starts when a button is pressed even if there is only one passenger. On the other hand, the "Push type" can be considered as an escalator. An escalator continues to supply (push) regardless of whether there is actual demand (passenger). In addition, "Push type" corresponds to a model for trains, buses, and airplanes for which supply (push) is based on demand forecast by time period and route. There may be various forms between "Push type" and "Pull type" depending on inventory forms of materials, work in progress (WIP), and finished items and how to deal with the actual demand in supply chain management.

5. COWIP (CONSTANT WORK IN PROCESS)

The CONWIP system is a generalized form of the Kanban system. Like Kanban, CONWIP uses cards to limit the WIP of a system; unlike Kanban the cards are allocated to a system of workstations instead of just one. This difference allows CONWIP to be applied in production environments that are detrimental to the Kanban system. In a CONWIP system the cards get attached to batches only at the first station. The card remains affixed to the batch until the batch has finished processing on the final workstation of the CONWIP system and the batch is used to satisfy a customer’s demand. The released card is then returned to the initial workstation of the CONWIP line and to authorize the entry of a new batch into the system.
Under a CONWIP system enough cards should be allocated to ensure the bottleneck is fully utilized. If the number of cards is insufficient the bottleneck starves and thereby reduces the system’s throughput.

![CONWIP System Diagram](image)

**Figure 3 CONWIP**

Even though CONWIP generally provides improvement over Kanban and MRP / MRPII, it does have its share of shortcomings. Some of them are listed below.

- Kanban systems can achieve higher throughput with lower WIP in some situations over CONWIP systems.
- CONWIP systems cannot be successfully implemented in a job shop environment.
- Incorrect card or information determination can lead to increased WIP or lost throughput for the system.
- Machine breakdown can bring the entire CONWIP system to a halt.

6. CYCLE TIME ANALYSIS FOR CONWIP PROCESS

The feeder line systems to determine the relationship of the samples parameters mean and variance with each other. The parameters under consideration are throughput, WIP and cycle time. The throughput and WIP values represent the average throughput and WIP of sixteen trials where each trial produced 4000 batches. The cycle time is the average cycle time of 4000 batches.

![WIP Analysis Graph](image)

**Figure 4 WIP ANALYSIS ON 3 MACHINE LINES**

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Figure 4 provides the observed WIP for feeder lines managed under a MRP system with constant inter arrival times. The WIP variances are equal within any MRP system regardless of the number or position of the bottlenecks, given that inter arrival times are 300, 301 or 302. In 75 out of 90 statistical comparisons, the WIP means and variances in any single bottleneck or dual bottleneck systems are equal regardless of the bottleneck location, given inter arrival times of 300 to 305. As the number of bottlenecks increase, the WIP increases.

![Throughput Analysis of 3 Machine Lines](chart)

**Figure 5** Throughput Analysis of 3 Machine CONWIP Lines– Bottleneck Position Constant

As the number of cards allocated to CONWIP systems increase, the throughput variances of the CONWIP systems increase, given identical bottleneck positions. The throughput variances of single bottleneck CONWIP systems at five cards are equal to the throughput variances of single bottleneck CONWIP systems at six cards; given the bottleneck positions are identical. The throughput variances of dual bottleneck CONWIP systems at four, five, and six cards are identical, given identical bottleneck positions. The throughput means of CONWIP systems increase as the number of cards increase regardless of the number of bottlenecks, given identical bottleneck positions.

**7. CONCLUSIONS**

Managing the nonbottleneck feeder lines with a pull system can eliminate the need for the synchronization process. In order to eliminate the need, the nonbottleneck feeder lines are managed in such a way that if left unhindered will achieve a greater throughput than the bottleneck feeder lines. Since the bottleneck feeder lines determine when the nonbottleneck feeder lines release a card, the throughput and the WIP of the nonbottleneck feeder lines remain in check.

An additional advantage of managing the nonbottleneck feeder lines with a pull system is reduced system WIP. Even with these advantages, the hybrid pull/push-push control system does have its shortcomings. If the nonbottleneck feeder lines are not managed properly, a pure-birth process will result. Also, given that the nonbottleneck feeder lines are managed properly, the maximum throughput attainable in the hybrid systems is identical to the equivalent assembly systems managed by a synchronized push system.

Through the analysis performed in this paper, the following three statements have been shown to be true for assembly systems. Given that the flow lines are in equilibrium, by managing the assembly system with a push system, batch synchronization must occur to prevent a pure-birth process from developing. Given that the flow lines are in equilibrium, by
managing the nonbottleneck feeder lines with a pull system, the WIP of the system can be reduced. Given that the flow lines are in equilibrium, by managing all feeder lines with a pull system, the WIP of the system can be reduced, a pure-birth process cannot occur, and increased throughput may be achieved.

REFERENCES


