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REVIEW ON JUST IN TIME TECHNIQUES IN MANUFACTURING SYSTEMS

Agrawal, N.
Manufacturing Process and Automation Engineering Department, Netaji Subhash Institute of Technology, Sector-3, Dwarka, New-Delhi-110078
e-mail: n_nsit@yahoo.co.in

Abstract
The control policy affects performance of a manufacturing line and can be classified as push, pull, or combination of pull and push. A pull or just-in-time (JIT) production system is a philosophy or an approach of the manufacturing system in which order release occurs due to physical removal of finished inventory in response to the customer demand. In this paper, we review the behavior of a manufacturing system in terms of performance parameters under the control of different JIT techniques. The considered control policies are kanban, CONWIP, and hybrid which are based on planned elimination of all waste and continuous improvement of productivity. A separate comparison among all the control policies in terms of performance parameters has also been included in this study. At the end, a table summarizes the use of JIT strategy or its techniques such as kanban, CONWIP and kanban-CONWIP (referred as hybrid) in manufacturing systems from the internationally reputed researches.

Key Words: JIT, Control Policies, Kanban, CONWIP, Hybrid

1. INTRODUCTION

JIT is a concept for producing a required volume of required item at a required point of time (Kimura and Terada, 1981). This concept was developed by Ohno (1988), to meet out the global competition, in which the work-in-process inventory (WIP) is managed and controlled more accurately than the Material Requirement Planning (MRP) -production system to reduce the production cost (Golhar and Stamm 1991 and Monden 1981).

In other words- Just-In-Time (JIT) manufacturing is closely associated with the principles of pull production control. Releases are authorized by material withdrawal from the output inventory of the production system, or an endogenous signal determines whether a release is allowed or not. Thus pull system is controlled by downstream information and is inherently make-to-stock. For example closed lines are pull systems because buffer spaces act as stock voids to trigger releases (Berkley 1992 & Gaury et. al. 2001). With the above discussion, following objectives of pull system can be listed as:

- Producing the right part in the right place at the right time.
- Eliminating waste due to any activity that increased cost without adding value, i.e. unnecessary movements of materials, excess inventory, faulty production methods, and rework etc.
- Improve profits and ROI (Return On Investment) by reducing inventory levels, increasing the inventory turnover rate, reducing variability, and improving product quality.
- To reach the goals of driving all inventory buffers toward zero by eliminating errors leading to defective items since there are no buffers of excess parts.
- Implement quality program, for supplier quality assurance, for workers, to understand the personal responsibility, to stop production when something goes wrong, to indicate line slowdowns or stoppages, and to record and analyze causes of production stoppages.
- Stabilize and level the MPS (Master Production Schedule) with uniform plant loading by creating a uniform load on all work centers through constant daily production.

- Meet demand fluctuations through end item inventory rather than through fluctuations in production level.
- Try for single setup times or “one touch" setup through, better planning, process redesigning, and product redesigning, using specialized equipment. Single setup times also allow economical production of smaller lots.
- Reduce lead times by moving work stations close together; applying group technology and cellular manufacturing concepts, reducing queue length, reducing delivery lead times through close cooperation with suppliers, and achieving the idle lot size of one unit.
- Use machine and worker idle time to maintain equipment and prevent breakdowns.
- To train workers to operate several machines, to perform maintenance tasks, and to perform quality inspections.
- Implementing the Toyota Production System concept of “respect for people” for a good relationship between workers and management.
- Use a control system such as kanban (card) system to convey parts between work stations in small quantities.

As shown in Figure 1, pull or JIT applies primarily to repetitive manufacturing processes in which the same products and components are produced over and over again. The basic elements of JIT were developed by Toyota in the 1970's, and became known as the Toyota Production System (TPS). The general idea is to establish flow processes by linking work centers so that there is even and balanced flow of materials throughout the entire production process (Al-Tahat and Mukattash 2006).Unfortunately pull systems do not lend themselves to all business types because of, product types, lead times and any stock holding arrangements with customers. However, there are so many benefits by adapting JIT techniques, which are listed in Table I.

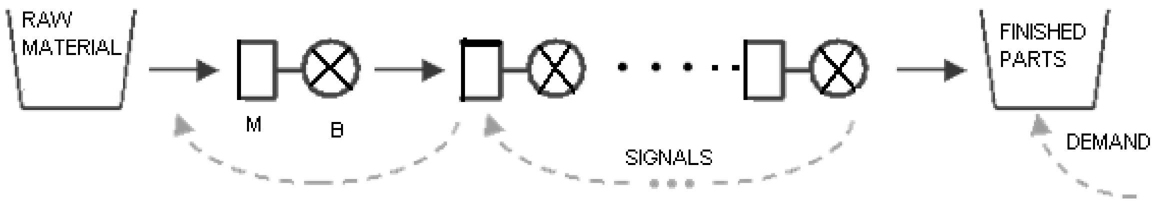

Figure 1: Pure pull or JIT system.

Table I: Pull system benefits.

Reduces Costs	**Improves Quality**	**Improves Customer Service**	**Maintains Flexibility**	**Logistical Benefits**
• reduces average WIP • reduced space • little rework	• improved defect detection • improved communication	• short cycle times • reduce sources of process variability • promotes shorter lead times	• avoid direct congestion • less reliance on forecasts • promotes floating capacity	• efficiency • robustness

With the above discussion we have come to these remarks that the traditional manufacturing methods have a target throughput which has to be specified and the actual throughput of the system has to be monitored which is not quite suitable for a production system in present scenario, however, controlling the amount of work-in-process or the finished goods inventory is more easy than that controlling the throughput or cycle time.

But the inventory-based control systems react to the changes in inventory level directly. This may leads over reacting to natural variation of the demand process instead of reacting only to the shifts in demand arrival rate. Therefore, a demand detecting mechanism is needed to determine whether a real change in demand rate occurs (Veatch and Wein 1994). Finally, it is noticed (Pandey and Khokhajaikiat 1996) that traditional systems are also bad during execution than the JIT systems.Therefore, to meet customer expectations with on-time delivery of correct quantities of desired specification without excessive lead times or large inventory levels, pull production control is required. The pull control systems may also be further divided as kanban, CONWIP, Hybrid etc. on the basis of the sequence of order release, customer order arrival, material withdrawal and production, when to switch control, and where control is required (Karaesmen and Dallery 2000, Jodlbauer and Huber 2008 & Ono and Ito 2004). Thus, the following subsections describe the exhaustive reviews on Kanban, CONWIP, and Hybrid.

2. KANBAN SYSTEM

Dasci and Karakul (2008) presented a model to analyze a manufacturing system which is operating under pull-type control and shows pull production control is often implemented using kanban systems. The Kanban control was originally used in Toyota production lines (Hopp and Spearman 1996). Kanban control policy links production activities and transmitted demand information from finished buffers to the preceding workstation using cards called “kanban” (Berkley 1992 and Philipoom et. al. 1987). There are many implementation forms of Kanban e.g. Price et. al. (1994) reviews optimization models of kanban systems, Zhoua et. al. (2006), employed kanban policy in remanufacturing process for determining the system dynamic performance of a hybrid inventory system, Qi Hao and Shen (2008), model complex kanban based material handling system in an assembly line using both discrete event and agent-based technologies through hybrid simulation approach. Perros and Altiok (1986) described a Kanban controlled unreliable manufacturing system in which the machine failure and repair rates were assumed to follow exponential distributions. Material flow in the system was controlled by manufacturing blocking discipline. Kanban system especially in the upstream stages, may not respond quickly enough to changes in the demand (Deleersnyder et. al. 1989 and Tayur 1993).

3. CONWIP SYSTEM

Another considered policy in this research is CONWIP which is a generalized form of kanban and initially proposed as a pull alternative to kanban (Spearman et. al. 1990). It is such a policy where a raw part enters to the system after servicing of a finished part to the customer in response of a demand. The aim of CONWIP is to combine the low inventory levels of Kanban with the high throughput of MRP System. CONWIP also shared the benefits of kanban such as shorter lead times and reduced inventory levels while being applicable to a wide variety of production environments (Koh and Bulfin, 2004).

4. HYBRID (KANBAN- CONWIP)

Much research has been done on individual control systems, only few comprehensive hybrid studies exist i.e. Generalized Kanban control proposed by Buzacott and Hanifin (1978) based on kanban and base stock control policies. In CONWIP policy, inventory levels are not controlled at the individual stages hence high inventory levels building up in front of bottleneck stages. Bonvik et. al. (1997), proposed hybrid policy which is a combination of Kanban-CONWIP to reduce loose coordination between production stages in a CONWIP lines. Hybrid policy can be implemented as a straightforward modification to a kanban policy, simply by routing kanbans from the finished goods buffer to the first production stage instead of the last.

5. COMPARISON OF THE JIT TECHNIQUES

Several researches demonstrate comparisons between kanban & CONWIP considering various performance parameters of manufacturing line. Reviews on pull systems also showed that few comparison studies have compared performance of CONWIP and hybrid (kanban-CONWIP) and kanban CONWIP and hybrid systems through simulation, experimental, analytical models and case studies. With the conclusion of the theoretical statements and simulation study of CONWIP, Spearman et. al. (1990), proposed that the CONWIP system can be used by any manufacturing system where the utility of kanban system is limited. This shows the superiority of CONWIP pull system is an alternative to kanban system.

Yang (2000) compared different kanban and CONWIP system and showed that kanban produces the longest mean customer waiting time with high WIP. Gaury et.al. (2000), described a methodology using evolutionary algorithm and discrete-event simulation for the choice of a pull production-control strategy and model Kanban, CONWIP, and Hybrid lines with six, eight, and ten stages. In a flow line model based on an actual system in a Toyota assembly factory, Bonvik et. al. (1997) showed the comparison in some specific situations. While comparing the production policies, the hybrid control policy demonstrated superior performance in achieving a high service level target with minimal inventories, closely followed by CONWIP. The performance measures used are: (i) service level or fill rate (ii) amount of inventory or WIP. Deterministic demand situation is assumed. Cases were considered including both constant and time-varying demand rates. Spearman and Zazanis (1992), showed that CONWIP produces a higher mean throughput than Kanban. In the same scenario, Muckstadt and Tayur (1995) showed that CONWIP produces a less variable throughput and a lower maximal inventory than Kanban. In a survey paper, Framinan et. al. (2003), discussed operations and applications of different CONWIP production control systems with detailed comparisons. Takahashi et. al. (2005) applied Kanban, CONWIP and synchronizes CONWIP to supply chains in order to determine the performances of a system. They considered supply chains containing assembly stages with different lead times. Geraghty and Heavey (2005) also presented a comparison of the performance of several pull-type production control strategies in addressing the service level v/s WIP trade-off in an environment with low variability and a light-to-medium demand load. Gstettner and Kuhn (1996), found that Kanban achieved a given throughput level with less WIP than CONWIP. Hodgson and Wang (1991) presented strategy where the first two stages 'push' and all other stages ‘pull’. They did not compare the different control policies and showed only the results of this hybrid combination.

Paternina and Das (2001) applied a simulation-based optimization technique called Reinforcement Learning (RL) and a heuristic policy named Behavior-Based Control (BBC) on a four-station serial line. The numerical results were used for comparison of control policies such as CONWIP, kanban and other hybrid policies on the basis of total average WIP and average cost of WIP with two different (constant and Poisson) demand arrival processes. Duri et. al. (2000) and Geraghty & Heavey (2004) compared policies in a different scenario for a specific automobile assembly line.

6. COMPARISON IN TERMS OF PERFORMANCE PARAMETERS

For comparing of different policies in terms of the performance of a manufacturing system, various performance parameters have been considered in several research papers, Gupta and Gupta (1989), concluded that high production rates can be realized only when the number of Kanbans is chosen optimally. Framinan et. al. (2006) have been established the correct number of cards in pull systems that can be addressed either statically (i.e. card setting), or dynamically (i.e. card controlling). They reviewed the different contributions regarding card controlling in pull systems (especially for CONWIP) and then a new procedure was proposed and tested under different environments. Philipoom et. al. (1987), described factors that influence the number of kanbans required in implementing JIT production techniques. They include throughput, process variation, machine utilization, and processing times. Takahashi (2003) and Takashashi & Nakamura (2002), proposed a reactive control mechanism for Kanban control system. The system adjusted the amount of Kanban cards according to a detected change in demand process using the time series data of the finished goods inventory level. Chan (2001) presented the effect of kanban size on various parameters i.e. in process inventory, service level or fill rate, unsatisfied order, manufacturing lead-time.

Kern et. al. (1996) examined the relative effectiveness of various rescheduling policies by a simulation experiment in JIT manufacturing environment. They analyzed schedule instability, total units of sales lost and average finished inventory. Alabas et. al. (2002) found that the Tabu search requires less computational efforts when compared to genetic algorithm (GA), simulated annealing (SA) and the neural network meta-model. They have used algorithms to find the optimum number of kanbans with the minimum cost by a simulation model. Tang et. al. (1993) used Taguchi method in the simulation experiments to study the relationship between the multiple performance measures and some given dispatching rules. The parameters which they used are utilization, number of machines buffer size and work in process for the operations planning and scheduling problems in FMS.

Tardif and Maaseidvaag (2001) introduced a new adaptive kanban-type pull control mechanism which determined the timings to release or reorder raw parts based on customer demands and inventory back orders, in order to maximize marginal benefits for predicting steady state performance of a manufacturing system. Petroni and Rizzi (2002) used average WIP, average Flow (production lead) time, Mean Tardiness as performance measures for predicting performance of a manufacturing system. Shahabudeen et. al. (2002 & 2003) designed single and two cards dynamic kanban systems using a simulated annealing algorithm. They proposed a universal test based on percentage zero demand (PZD), mean lead-time (MLT) and mean total WIP (MTW) and may be suited for the MOP (measure of performance) in any JIT system. Koukoumialos and Liberopoulos (2005) have been developed a general purpose analytical approximation method for the performance evaluation of a multi-stage, serial, echelon kanban control system. An iterative procedure was used to determine the unknown parameters of each subsystem. Jing (2003) presented about the improving the performance of job shop manufacturing by reducing setup/processing time variability. He has measured three factors for shop performance which are average work-in-process (WIP) inventory, average flow time and average set up time to processing time ratio.

Table II summarizes the use of JIT strategy or its techniques such as kanban, CONWIP and kanban-CONWIP (referred as hybrid) in manufacturing systems from the internationally reputed researches.

Table II: JIT applications.

Author	Year	Application	Techniques
Wu and Lai	2007	Presented a production scheduling problem in a MNC of Hong Kong. A series of Lemmas and a polynomial-time algorithm have presented to determine the optimal due window and sequence.	JIT
Wodecki	2008	Considered a single-machine job scheduling problem where the objective is to minimize the weighted sum of earliness and tardiness (E/T). Proposed partitioning of permutation into subsequences (blocks) and replaced sets of moves with its representatives, coefficients of a goal function.	Tabu search and JIT

Farahania & Elahipanah	2008	Optimized the total cost and service level in distribution of a supply chain.	G.A and JIT
Chang et.al.	2008	Proposed a mixed-integer optimization approach that can be used to joint optimization for the multi-buyer and single supplier. All decision variables obtained were executable integers for the planning horizon of one time period.	Genetic algorithm and JIT
Sandanayake et.al.	2008	Applied linear mathematical modeling and computer based simulation tools to identify the impact of selected key JIT parameters on performance in an automotive component manufacturing environment.	Simulation modeling
Rabbani et.al.	2008	Determined number of kanbans in a supply chain system via Memetic algorithm. Authors also tried to model supply chain system with regard to costs under JIT manufacturing.	MINLP, JIT, Kanban
Hao and Shen	2008	Demonstrated a hybrid simulation technique for modeling complex material handling processes in an assembly line using discrete event and agent-based technologies.	Simulation, JIT, Kanban
Mia and Winata	2008	Revealed that JIT application is positively associated with managers' use of broad scope information provided by the management accounting system (MAS information) which in turn, is positively associated with the use of ICT.	JIT, MAS information, ICT
Kojima et.al.	2008	Proposed algorithm for exact performance evaluation of the SCM in JIT environment with two kinds of kanbans under stochastic demand. The parameters considered are stationary distributions of the inventory level, production quantities and total backlogged demand in each stage.	JIT, Kanban
Martin et.al.	1998	Determined the number of kanbans and lot sizes to maximize system performance. System objectives included minimizing cycle time, operation costs and capital losses.	Tab search, Simulated Annealing
Ramanan and Rajendran	2003	Proposed simulated annealing algorithm for solving the kanban-controlled flow shop scheduling problems to Minimize the Make span of Containers.	Simulated annealing (SA), Kanban
Panayiotou and Cassandras	1999	Developed an algorithm to maximize the throughput of a kanban manufacturing system with arbitrary arrival and service process distributions by adjusting the number of kanban allocated to each production stage while maintaining the total work-in-process inventory at any desired level.	Perturbation analysis
Krishnamurthy et. al.	2004	Compared the performance of MRP (push) and kanban (pull) for a multi-stage, multi-product manufacturing system. Criteria for measurement were safety lead time and safety stock.	Simulation, kanban

I.p et.al	2002	Proposed a CONWIP controlled FMS model and node type characteristics concept have been used to describe the constraint in FMS.	Simulation, CONWIP
Cao and Chen	2005	Developed a nonlinear mixed integer programming model for a CONWIP production system where an assembly station is fed by two parallel fabrication lines. Performance of the system measured by the total set-up time and the work load balance on the fabrication lines.	Traveling salesman problem (TSP)
Yang et al.	2007	Solved a multi-constant work-in-process (multi-CONWIP) pull strategy problem by an evolutionary simulation optimization approach.	Evolutionar y algorithms, Simulation
Ovalle, and Marquez	2003	Presented the benefits of the CONWIP system in different production environments and discuss the possible utilization of this system to manage the entire supply chain.	Simulation and CONWIP
Huang et.al.	2007	Presented an alternative analysis of CONWIP at an aggregate level for the decision-making about the SC. using the lamp manufacturing industry in mainland China.	Simulation and CONWIP
Ghamari	2008	Analyzed the performance comparison between Kanban and CONWIP controlled assembly systems with respect to the kanban distribution.	Kanban and CONWIP

7. CONCLUSION

This paper has provided a broad and specific review on issues related to application of JIT techniques in manufacturing systems. Various JIT techniques such as kanban, CONWIP and kanban-CONWIP (referred as hybrid) have been reviewed in depth to provide general background information on the field of study. Specific reviews on comparison of considered policies have also been provided. Review also covers previous studies conducted by various researchers on comparison in terms of performance parameters.

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