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Restricted work-in-process: A study of differences between Kanban and CONWIP

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ABSTRACT

This article presents a simulation study over a small supply chain, where the amount of work-in-process (WIP) is restricted. The supply chain consists of five linked machines, or production facilities, with stochastic operation times. A number of test cases are made where the number of jobs in the machines and the buffer areas are restricted. The restrictions are designed both in the Kanban way, linked to every machine, and in the CONWIP way, connected only to the total production line. But no Kanban-cards and -cells are involved in our study, just restricted inventories between the machines. With the same amount of limited WIP, CONWIP-control compared to Kanban-control presents a higher throughput rate, less time between jobs out, but the jobs stay on average longer in the system. The stochastic operation times cause that the upstream machine sometimes consumes the jobs in a rate that the downstream machine does not catch up with, therefore all available storage room temporarily are not used. Kanban- and CONWIP-control presents the same amount of average outflow per time unit with the same variation in operation times and with the same amount of real average WIP. But Kanban-control causes a lower utilisation of present available storage room and storage equipment than CONWIP. The user of Kanban and CONWIP can only control maximum WIP and not average WIP; average WIP is a consequence of existing variations, so the difference is important. The coefficient of variation of the lead-times increases when WIP increases; this is very difficult to handle in practical applications. Restricted WIP that shortens the lead-time and decreases its variation is more important than if it is a "push" or "pull" system. Finally, it is argued that CONWIP-control is to prefer over Kanban-control in theory, but in practice there is a lack of CONWIP installation guidelines.

1. Introduction

Kanban is a technique for material and production control and performance. Originally presented as a Japanese technique Kanban was advocated for and spread by e.g. Monden (1983), Schonberger (1982, 1986), Shingo (1982), Sødahl (1984), etc. Similar techniques, two-bins, signal systems with numbered metal plates, etc., were used before in Nordic and western companies, not surprisingly because basically Kanban is a reorder point system but with a more visible reorder point. But the introduction of Kanban was a breakthrough for visible signal systems in western companies. The introduction of Kanban started a discussion of "pull" and "push" systems, where material requirements planning were considered as a push system and Kanban as a pull and just-in-time system.

When searching on the internet for pull and push systems the following definitions and categorisations of push versus pull can be found: push systems is said to

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mean “make all we can just in case”; and is said to be categorised by production approximation, anticipated usages, large lots, high inventories, waste, management by fire fighting, poor communication. Contrary pull systems is said to mean “Make what’s needed when we need it” and categorised by production precision, actual consumption, small lots, low inventories, waste reduction, management by sight, better communication. The same thoughts and reasoning can be found elsewhere even in textbooks for management; the good things are pull and the bad things are push and causes and effects are not separated.

There exist many attempts tot define push and pull, cf. Pyke and Cohen (1990) and Bonney et al. (1999). For example, Spearman et al. (1990) mean that a pull system does not schedule the start of jobs but instead authorises production. Bonney et al. (1999) show that the definitions of push and pull are inconsistent between different researchers and arguments about performance are sometimes circular, if the performance of a pull system is poor then it may be suggested that this is because the fundamentals of just-in-time are not being observed, whereas, if the performance of a push system is poor, then that is a consequence of it being a push system.

Spearman et al. (1990) introduced a pull alternative to Kanban named CONWIP (CONstant Work In Process), where the work-in-process (WIP) is not constrained at every operation or machine instead the number of WIP in a total production “flow” is constrained. A production flow that may consists of several operations or machines and not just one machine.

For example, Hopp and Spearman (1996, 2000) and Silver et al. (1998) show the importance of restricted WIP. Too much (WIP) prolongs the time it take from start of production until it is ready to leave the production facility, to the next step in the supply chain or reach the end user. Too little WIP, when there are variations in production times and quantities, constrains the outflow by “starving” and “blocking” to a lower level then what would be the case with more WIP. (When there are a number of machines connected to a supply chain and no large enough buffers between the machines; a machine is starving when it cannot work because it has to wait for a job from the upstream machine and the machine is blocked when it cannot work with a new job because it cannot pass the finished job to the downstream machine, still working with its current job.)

Like Pyke and Cohen (1990) we mean it is not possible or useful to label a manufacturing system as being entirely push or pull. Most companies need both authorised and forecasted scheduled production; but very important the companies need restricted WIP. Push and pull are characteristics of the underlying decision-making process, which will contain elements of push or pull to varying degrees. To accomplish a short delivery time to the customers most companies must start production of components and semi-manufactured products according to forecasts often long before the customer order of the end product arrives. To achieve this material requirement planning (MRP) or reorder point systems (ROP) is mostly used in practical computer-based applications. Therefore, our interest also emanates from an alternative to MRP named cover-time planning (CTP) (cf. Segerstedt, 2006); CTP has similarities to CONWIP, WIP, in the machines and in stock for an item is constrained according to its current forecasted demand rate and expected lead-time. All these explain our interest in restricted WIP, Kanban and CONWIP and the reason we examine it in this simulation study. Despite the common attention to Kanban and CONWIP (Framinan et al. (2003) present a review, more recent publications e.g. Geraghty and Heavey (2004), Takahashi et al. (2005)), we have not found a similar study presenting similar results. Bonvik et al. (1997) also compare Kanban and CONWIP but in totally different way. The upcoming text has the following outlay. In Section 2, we present the test example and describe the simulation model. Thereafter, in Section 3, we present results from the simulations and its findings and finally some conclusions, discussions and extensions in Section 4.

2. Test example and simulation model

This study is triggered from and based on a small problem excellent described in Silver et al. (1998, p. 694). A job shop has five machines, illustrated in Fig. 1. We assume that an average of 60 min processing time for each job on each machine. All jobs have the same routing: first they are served in Machine 1, then in Machine 2 and last in Machine 5 before they leave the system. We study a number of test cases where work-in-process (WIP), the maximum number of jobs in the buffer areas (Queues 1–4) and in the machines are restricted. No Kanban-cards and no Kanban-cells are involved in our study, just restricted inventories between the machines. So our study is not really a study over a Kanban system, but it is a study over when the WIP restrictions are designed both in the Kanban way, linked to every machine, and in the CONWIP way, connected only to the total production line.

Every machine is assumed to have the same variation in operation times, three different variations were tested; operation times uniformly distributed between 50 and 70 min (60 ± 10, coefficient of variation $c_v = \sigma/m = 0.096$), between 30 and 90 min (60 ± 30, coefficient of variation $c_v = 0.29$) and operation times uniformly distributed between 10 and 110 min (60 ± 50, coefficient of variation $c_v = 0.48$).

For both Kanban and CONWIP several measures are monitored: *time in system*, for each job the number of minutes between moving into Machine 1 and moving out of Machine 5; *time between jobs out*, the number of minutes since the last job left Machine 5 and this job, for each job; *total number of jobs produced* out of Machine 5 during total simulation time; *current jobs in the system*, both in machines and queues.

For every test case is studied/memorised the mean and the standard deviation of time in the system or lead-time, LT, for a job passing all five machines ($\geqslant 5\,h = 300\,min$); and achieved production, mean time between jobs out, P, ($\geqslant 60$ min/unit). (Like Silver et al. (1998) we get for only one job in each machine ($WIP \leqslant 5$) and operations times uniformly distributed 60 ± 30 an outflow of 0.78 units/h, cf. Table 2: $60/76.99 = 0.78$.)