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# COBACABANA (Control of Balance by Card Based Navigation): An alternative to *kanban* in the pure flow shop?

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ABSTRACT

*Kanban* systems are widely applied in practice as they represent a simple yet effective means of controlling production. But they suffer from a lack of load balancing capabilities, which hinders their application even to pure flow shops if there is variability. In response, this study focuses on COBACABANA (Control of Balance by Card Based Navigation), a card-based production control approach based on the Workload Control concept that was recently introduced in the literature. COBACABANA was developed for high-variety job shop contexts, but we argue it can also provide an important control alternative to *kanban* systems in pure flow shops. We first show that, in the pure flow shop, the control loop structure of COBACABANA resembles that of a *kanban* system when the flow of jobs is controlled. But a distinct difference is COBACABANA's unique focus on load balancing. Using simulation, we then demonstrate the potential of COBACABANA to improve performance in a pure flow shop with high demand and processing time variability. Results show that a fixed gateway station – inherent to a pure flow shop – presents a structural constraint that makes COBACABANA's original starvation avoidance mechanism, which injects work to a starving station, dysfunctional. An alternative is prioritizing jobs with short processing times at upstream stations to ensure quick replenishment takes place at downstream stations threatened by starvation. This has important implications not only for COBACABANA but for priority dispatching. Although card-based systems are typically combined with first-come-first-served dispatching, our results suggest this may be inappropriate in flow shops with processing time variability.



## 1. Introduction

In recent decades, repetitive manufacturers have simplified production control through the use of card-based control systems, particularly *kanban* systems that are an important element of just-in-time and lean production (e.g., Sugimori et al., 1977; Ohno, 1988; Shingo, 1989; Monden, 2011). *Kanban* systems are used to connect production stages or operations to one another to improve coordination, thereby regulating work-in-process and eliminating overproduction. They are commonly used in practice by a wide range of organizations that differ in size and production strategy. For example, White et al. (1999) – who surveyed companies that had implemented at least 1 of 10 so-called just-in-time practices – reported that about 50% of small and medium-sized manufacturers and 70% of large manufacturers had adopted *kanban* systems. Similarly, White and Prybutok (2001) reported that about 60% of non-repetitive and 70% of repetitive manufacturers that they surveyed had adopted *kanban* systems.

*Kanban* systems were originally applied to repetitive manufacturing, but their spread to non-repetitive shops, including pure flow shops with demand and processing time variability, has motivated much recent research. This recent body of work has sought to refine *kanban* systems so they can cope with variability (Lage Junior and Godinho Filho, 2010). But while some studies have attempted to address the problems that variability introduces by adjusting the number of *kanbans* (e.g., Takahashi and Nakamura, 1999; Dallery and Liberopoulos, 2000) or by establishing different loop structures (e.g., Gaury et al., 2001), Germs and Riezebos (2010) suggested that the poor performance of card-based systems in high-variety contexts may be explained by a lack of load balancing capabilities. Thus, adding load balancing capabilities may be a potential key to improving the performance of *kanban*-like systems in shops that feature variability.

In response, this study presents an alternative to a *kanban* system that has recently emerged in the job shop literature and incorporates load balancing capabilities: Control of Balance by

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Card Based Navigation or COBACABANA (see Land, 2009; Thürer et al., 2014a). COBACABANA is based on the (non-card based) Workload Control concept, which has been shown to significantly improve the performance of job shops both through simulation (e.g., Thürer et al., 2012, 2014b, 2015) and, on occasions, in practice (e.g., Hendry et al., 2013). Workload Control and, consequently, COBACABANA were designed to achieve the same leveling of workload to capacity that is achieved in repetitive manufacturing using lean tools, but while also allowing the company to offer highly customized products to its customers. It reduces the variability of the incoming workload that results from product customization rather than limiting variation in the product mix itself (Thürer et al., 2014b).

Although COBACABANA was developed for job shops, it is argued here that it can also provide an important control alternative to *kanban* systems in pure flow shops with high variability in terms of the occurrence of demand and/or processing times. This is a common shop type, e.g., for companies that focus on producing prototypes and making small runs, e.g., of 1 to 4 units, sometimes referred to as 'one offs'. More specifically, the two main objectives of this study are as follows:

1. To compare the control structure of *kanban* systems and COBACABANA in a pure flow shop, i.e., where all jobs have to visit all stations in the same sequence.
2. To use simulation to demonstrate the potential of COBACABANA to improve performance in contexts where *kanban* systems typically fail: pure flow shops with high variability in terms of the occurrence of demand and processing times.

The remainder of this paper is organized as follows. *Kanban* systems and COBACABANA are first introduced and compared in Section 2 where we show that, in the pure flow shop, the control loop structure of the two systems resemble one another when the flow of jobs is controlled. The difference is COBACABANA's unique focus on load balancing. A simulation model of a pure flow shop, which we use to evaluate two variants of COBACABANA, is then outlined in Section 3. The simulation results are presented and discussed in Section 4 before the paper concludes in Section 5, which includes managerial implications and future research directions.

## 2. *Kanban* vs. COBACABANA

This section provides an overview and comparison of the *kanban* and COBACABANA systems. *Kanban* systems are first discussed in Section 2.1 before the new COBACABANA system is introduced in Section 2.2. A reflection on the *kanban* literature is then provided in Section 2.3.

### 2.1. *Kanban systems*

The Japanese word '*kanban*' translates literally to 'watch over board for a period of one' – it is a common term that means signboard or billboard (Protzman et al., 2010). A *kanban* system is an order release system that withholds work from the shop. Work is not released immediately to the shop floor – it has to wait for authorization (through *kanban* cards/signals that trigger release). Since the number of *kanban* cards in the system is restricted, it is essentially an input/output control system, where the output rate determines the input rate.

While the original *kanban* system is mainly described as an 'inventory control system', we focus on its use as an 'order control system'. Most production processes involve both systems, with the two separated at the inventory/order interface (Hopp and Spearman, 2004) or order penetration point (Olhager, 2003). The inventory/order interface emerges at the point where a job is linked to a customer; linked, according to our definition, means receiving a 'mark' or 'genidentity' in the sense of Reichenbach (1999). This essentially means that jobs are interchangeable in the inventory control system while, in the order control system, they are not. The *kanban* system – as an inventory control system – was developed to curb overproduction (Ohno, 1988; Shingo, 1989). *Kanbans* were used to signal from the downstream to the upstream station that parts are needed, which ensured that parts would only be produced if they would actually be used at a later stage of production. Since jobs are interchangeable, *kanban* cards are independent from individual jobs. Rather, they are dedicated to job classes. This decouples the control loop operating between two stages from all preceding stages, with production control exercised through a chain of interlinked pairs of stages (see Fig. 1).

In this study, we focus on a pure flow shop, where the flow of individual jobs is controlled – i.e., an order control system. In an order control system, the nature of the control problem is different from that in an inventory control system. Since jobs are no longer interchangeable, *kanban* cards have to be dedicated to individual orders. But, if it is dedicated to an individual order, the *kanban* card (and thus production) is blocked until the order belonging to that *kanban* arrives at the station. In other words, *kanban* cards now not only represent the direct load queuing at a station but also the indirect load that is still upstream. The further downstream a station is, the higher its indirect load. For example, the *kanban* card of the 3rd station stays about three times longer at the station than a *kanban* card for the first station (see also Land, 2009). This may explain why, in studies that sought to identify the optimum number of *kanban* cards in circulation for each station (e.g., Gstettner and Kuhn, 1996), downstream stations had a much higher number of cards. This phenomenon significantly changes the *kanban* system. Production is no longer controlled by the last station, which should have the highest number of *kanban* cards in circulation, but by the first station, which should have the lowest number of *kanban* cards in circulation.

The above change to the control problem was recognized by the introduction of so-called job-order *kanbans*, which are issued for each job and different from other types of *kanban* cards used for recurrent production (see, e.g., Monden, 2011). Similarly, the card-based Constant Work-in-Process or ConWIP system (e.g., Spearman et al., 1990) establishes only one feedback loop from the final to the first station (or gateway station) and triggers release whenever a job is completed. In general, however, ConWIP suffers from the same weakness as *kanban* systems – a lack of load balancing capabilities (Germs and Riezebos, 2010). Even the Paired cell Overlapping Loops of Cards with Authorization (POLCA; e.g., Suri, 1998; Riezebos, 2010) system, which was designed to cope with more variability than *kanban* and ConWIP, only accounts for routing variability. POLCA represents an extension of a *kanban* system that allows a station to enter into a control loop with more than one station but, in a pure flow shop, POLCA and *kanban* systems are the same.

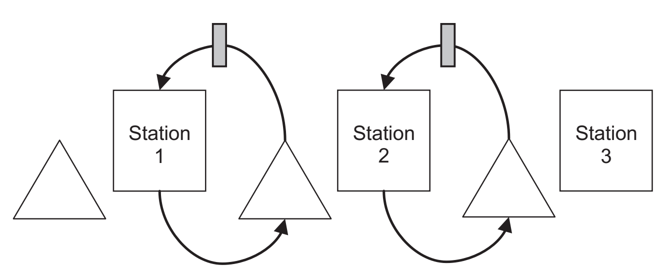


**Fig. 1.** Kanban system – loops between queues and preceding stations that build a chain of interlinked pairs.